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Application of Advanced Speech Technology in Manned Penetration Bombers

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NOTICE

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This report documents research on the potential use of speech technology in a manned penetration bomber aircraft (B-52/G and H). The objectives of the project were to analyze the pilot/copilot crewstation tasks over a three-hour-and forty-minute mission and determine the tasks that would benefit the most from conversion to speech recognition/generation, determine the technological feasibility of each of the identified tasks, and prioritize these tasks based on these criteria. Secondary objectives of the program were to (1) enunciate research strategies in the application of speech technologies in airborne environments, and (2) develop guidelines for briefing user commands on

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the potential of using speech technologies in the cockpit.

The task analysis proceeded by breaking down the elements of each crewmember's activity into its input and output modalities (i.e., manual/visual, vocal/auditory). Human performance data in time sharing conditions were used to formulate guidelines for choosing the best candidates for speech technology. Manual/visual time sharing (e.g., flight control and radio frequency changing) was a prime target for elimination by switches to speech input for the discrete tasks. Anthropometric difficulty (reach distance and visual fields) is also used to choose speech task candidates. A third criterion, information retrieval, was also used as suggested by pilots. Tasks were scored by a group of instructor pilots by questionnaires assessing the utility of switching each task candidate to speech input or output.

The results of this study indicated that for the B-52 crewmember, speech recognition would be most beneficial for retrieving chart and procedural data that is contained in the flight manuals. The verbal nature of these tasks (i.e., "display landing checklist") makes them natural candidates for speech recognition. Pilots also indicated preference for "programming tasks that would allow the crewmember to program warnings to automatically occur under certain conditions. Other control tasks such as altimeter setting, navigation system control, radio frequency changing, etc. had varying degrees of pilot utility. Technological feasibility of these tasks indicated that the checklist and procedural retrieval tasks would be highly feasible for a speech recognition system.

SUMMARY

This report documents research on the potential use of speech technology in a manned penetration bomber aircraft (B-52 G and H). The objectives of the project were to analyze the pilot/copilot crewstation tasks over a three-hour-and-forty-minute mission and determine the tasks that would benefit the most from conversion to speech recognition/generation, determine the technological feasibility of each of the identified tasks, and prioritize these tasks based on these criteria. Secondary objectives of the program were to: 1) enunciate research strategies in the application of speech technologies in airborne environments; and 2) develop guidelines for briefing user commands on the potential of using speech technologies in the cockpit.

The task analysis proceeded by breaking down each element of each crewmember's activity into its input and output modalities (i.e., manual/visual, vocal/auditory). Human performance data in time-sharing conditions were used to formulate guidelines for choosing the best candidates for speech technology. Manual/visual time-sharing (e.g., flight control and radio frequency changing) was a prime target for elimination by switches to speech input for the discrete tasks. Anthropometric difficulty (reach distance and visual fields) was also used to choose speech task candidates. A third criterion, information retrieval, was used at the suggestion of the pilots. Tasks were scored by a group of instructor pilots via questionnaires assessing the utility of switching each task candidate to speech input or output.

Each task was also scored on a technological feasibility scale that rated the task for the potential difficulty in implementing it in the cockpit. (Recognition tasks only were subjected to this procedure due to the general high feasibility of speech generation tasks with the current state-of-the-art

in this technology.) The factors that could be assessed in this study were: 1) vocabulary confusability given each vocabulary for all candidates; and 2) potential degradation of noise. Noise data were available on a mission segment basis.

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Research strategies were discussed for recognition and generation technologies. Issues for recognition were needed for connected vs isolated speech, feedback and prompting methods, activation/deactivation of speech system, vocabulary choice and verification, noise and environmental effects, and integration of the system into the existing communications system. For generation, pilot attention factors, conversational aspects, and performance evaluation were discussed. A general research strategy that was seen as most important was man-in-the-loop simulation.

A plan was also proposed for briefing the user community about the utility and capability of speech technologies. Briefing topics such as introduction to the technology, demonstrations, hands-on participation, and research issues should be included in presentations to pilots.

FOREWORD

This report details results from the application of a methodology for choosing and examining the most beneficial candidates for applications of advanced speech technology in the manned penetration bomber aircraft. It was prepared by Honeywell Systems and Research Center under USAF Contract No. F33615-80-C-3606. Mr. Eric Werkowitz was the contract monitor.

The author wishes to acknowledge the contributions of several key personnel to this program. The Strategic Air Command was integral in efficiently providing mission scenarios and pilot interviews. In particular, Major Stuart MacTaggart, 93rd Bombardment Wing, Castle AFB, CA, deserves special thanks for arranging initial data gathering and simulator visits, and especially for his contributions during the writing of the final report. Major Alan Osborne coordinated the gathering of the pilot questionnaire data.

The author participated in a training flight with the 319th Bomb Wing at Grand Forks Air Force Base during the performance of this program. Major Lou Beck and his crew deserve special mention for their coordination of, and patience during, the observation flight.

CONTENTS

CONTENTS (continued)

CONTENTS (concluded)

LIST OF ILLUSTRATIONS

LIST OF TABLES

SECTION 1

INTRODUCTION

The crew of the B-52 Stratofortress is on final approach for Grand Forks AFB when the aircraft commander announces an emergency condition. The two right outboard engines (7 and 8) are out, and the aircraft is beginning to exhibit unstable control characteristics. The flaps have been deployed. The crew must now quickly determine the minimum speed for directional control (MSDC) and proper thrust (EPR) to execute a safe landing.

The copilot presses his "voice-in" button on the yoke control and says "EMERGENCY" and "ENGINE OUT." The EVS displays the question "PRESSURE ALTITUDE?" The copilot says "TWO THOUSAND." The EVS displays a table of values for the minimum speed for directional control. A "NEXT" from the copilot gives the Engine Pressure Rating for these conditions. The transaction takes approximately twenty seconds. The appropriate values for EPR and MSDC for present conditions are noted by the copilot.

BACKGROUND

Recently, it has become possible for a human operator to converse with machines. Speech recognition and speech synthesis have both been successfully applied in many ground-based environments in industry. In the military cockpit, one may envision a significant reduction in manual and visual workload for crew members during periods of "time-sharing," or concurrent activities through the use of speech recognition and synthesis devices. This will be especially true when manual control (landing approach, terrain avoidance) or visual attention (target searching, sensor scanning) cannot be sacrificed.

This program has developed a methodology for careful examination and research in the implementation of such advanced speech recognition and synthesis technology in airborne environments. This integrated effort includes human factors analysis, user involvement, and intelligent use of technological projections. Mission analysis, workload assessment, pilot interviews, and consultation with Advanced Speech Technology (AST) system experts were used to ensure that the technology is correctly applied in situations that result in a major positive influence on aircrew/system performance.

PROBLEM OVERVIEW

The Mission and Aircraft

From the cockpit design viewpoint, the B-52 G/H aircraft is perhaps the most complex military aircraft in operation. Engine data monitoring alone requires scanning an array of 32 dials. Long and detailed checklists must be performed by the pilot and copilot in preparation for, and conduct of, mission phases. Numerous switching tasks and status checks are performed during the course of a flight by both of these crew members. Many of these tasks seem amenable to voice recognition, speech synthesis, or a combination of both in an interactive mode. A major problem is optimal choice of these tasks for AST.

The Technology

The past two decades have seen the rapid development of devices that listen and talk to human operators. Because of the complex problems of pattern recognition involved in human speech waveform analysis, speech recognition has required more research than speech generation. Speech recognition systems can be categorized into four major types:

- Speaker-Dependent (user must train device before use)
- Speaker-Independent (can be used by entire population of users)
- Isolated-Word (utterance restricted in short time, e.g., 2 seconds)
- Connected-Speech (accepts phrases or sentences from speaker)

Speaker-dependent, isolated-word systems have enjoyed recent success in many practical applications, and have decreased in price with microcomputing advances. Movement continues toward developing reliable speaker-independent, connected-word systems, although system costs remain high at present.

Speech generation systems can be divided into: 1) digitized speech systems; and 2) synthesized speech systems. The digitized speech systems operate by digitizing the analog speech wave form for each word and "playing back" the word by converting from digital to analog. Memory storage capability affects the intelligibility of these systems; e.g., as more memory is used, the system's intelligibility increases. Synthesized speech operates by modelling the human vocal tract electronically. Certain frequencies (formants) that dominate human speech are electronically excited to produce speech-like quality, although these systems are generally less intelligible. As memory capacity increases in microelectronic systems, the practicality of high quality digital speech will increase.

The User

A major factor in the success of speech recognition and synthesis systems in any application is user acceptance. The best recognition system can be worthless if the user is uncooperative or not confident in the successful operation of the device. The successful exploration of the application of any new technology in the cockpit requires coordination with the pilot

community. The years of training and operational experience that these individuals provide can help guide the application of AST and ensure that our ideas are operationally sound.

Because of the recent emergence of the technology, a detailed knowledge of AST is not prevalent. Knowledge of the current state-of-the-art in AST greatly increases the ability of the pilot to make valuable contributions. Therefore, a program that explores AST applications should include a method for briefing the user community on the current status of AST.

APPROACH

Our approach to solving the problems discussed in the previous section can be summarized by three major products:

- o Analysis of the most beneficial AST task candidates for this aircraft and assignment of technological and pilot utility rankings for those tasks.
- o A review of the major research issues in the application of speech to airborne systems.
- o A development of a successful set of procedures for briefing the user community on the capabilities and limits of AST in the cockpit.

These products are summarized in more detail below.

Analysis of AST Candidates and Rankings

Identifying the most beneficial AST task candidates for the B-52 G/H pilot/copilot crew stations has been a major effort of this program. Standard task analysis techniques combined with knowledge about the capabilities of the human operator to time-share among two or more activities were major ingredients for this analysis, as were subjective data collected through pilot

interviews. Once the set of best tasks was chosen, each task was ranked on its potential for reducing workload and on the technological feasibility of implementing it using AST. System experts were consulted to make technological judgments of current and future capabilities of AST systems applied to each task chosen. The results and procedures for this product are detailed in Section 2.

Research Strategies

The successful implementation of speech systems into the cockpit environment will depend upon the logical progression of research on several problems. A discussion of these problems and gaps in both recognition and generation technology is presented in Section 3.

User Education

In Section 4 we present an approach to briefing pilots about the potential of AST in the cockpit. Our experiences in the performance of this project have indicated that pilot opinion concerning speech technology can be greatly influenced by successful demonstrations and interactive discussions among pilots and crew members. In this section we outline details of a typical "briefing seminar" designed for personnel with little or no AST background.

SECTION 2

AST CANDIDATE SELECTION

TASK ANALYSIS

The first step in determining the best AST task candidates is analyzing all pilot/copilot tasks performed during typical missions. Our approach to this analysis is shown in Figure 1. The analysis begins with a government-furnished mission scenario covering the four highest workload mission segments that were anticipated to contain the best AST tasks. These segments were TAKEOFF, AIR REFUELING, LOW LEVEL BOMBING, AND RECOVERY. Using these scenarios in conjunction with pilot interviews concerning procedures, we then compiled task narratives covering every activity that the pilot and copilot perform. From these verbal descriptors of actions and information exchanges, we then create time-based event tables which list the appropriate sensory and motor channels presently used in performing the tasks. These data are also presented in chart form. The tasks are then categorized for their anthropometric (reach distance or visual field) and time-sharing (simultaneous task performance) characteristics. From these timeline charts, we then selected all tasks that could potentially benefit from switching to speech technology.

Mission Scenarios

The B-52 G/H mission scenarios used in this analysis were compiled from SAC briefings and documentation. They cover the four segments mentioned above. These segments were believed to contain the highest portion of manual-visual task workload for the forward two crew stations. The mission covered by these scenarios was approximately three and one-half hours long.

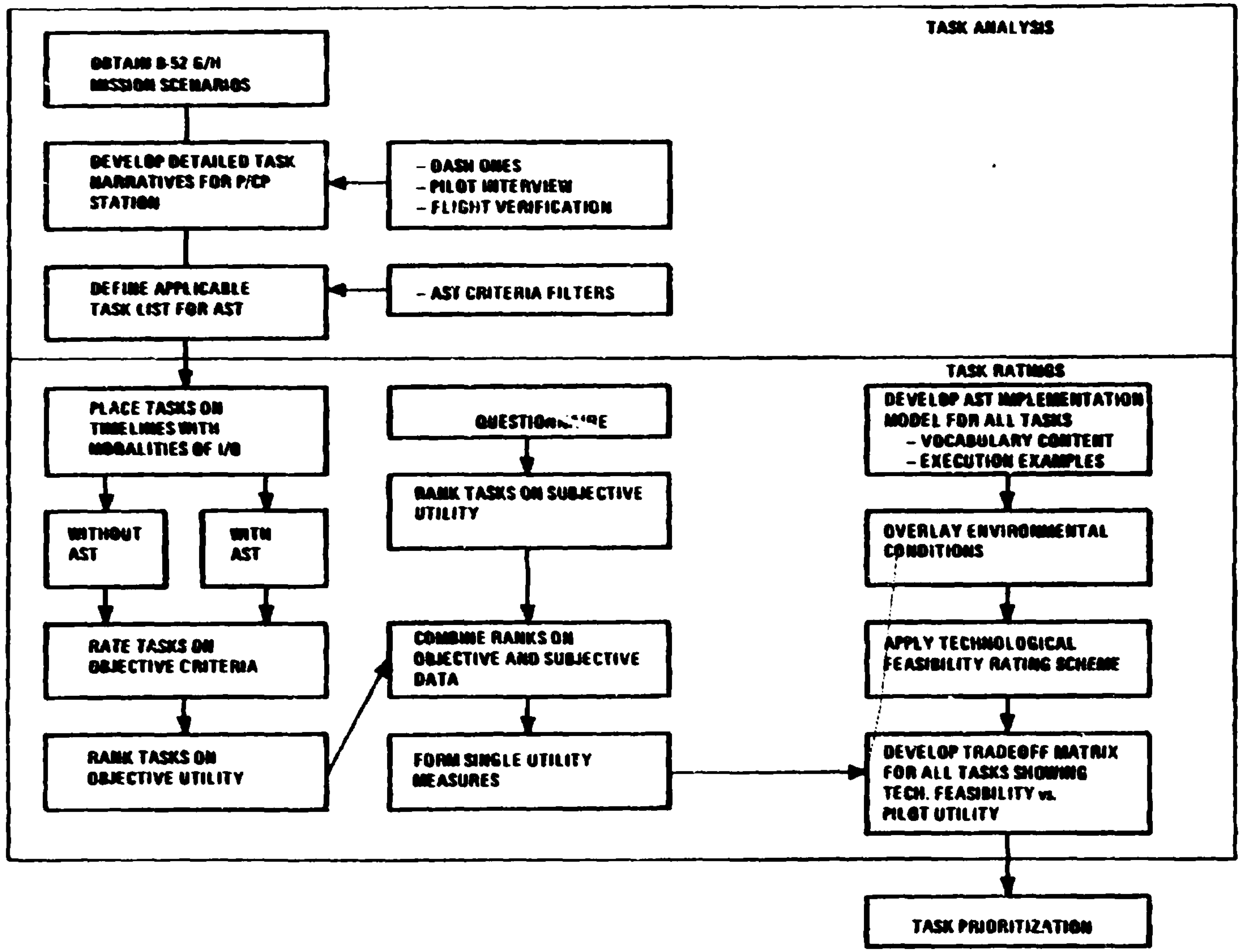

Figure 1. Task Analysis Approach

Task Narratives

The task narratives for the mission segments covered in the above scenarios are presented in Appendix A; an example is provided in Table 1. These data were obtained through several sources. A visit was made to Grand Forks Air Force Base to interview crewmembers on activities performed during a typical mission. The mission scenarios were used as a guide for this interview. The flight manuals, or "dash-ones," were also used to obtain all checklist information and procedures during a flight. Finally, the principal investigator took a training flight to verify the task narratives that had been compiled from the above two sources. This flight covered all mission phases except for air refueling. He also took a simulation flight for this segment to gain appreciation for the workload encountered by the crew during air refueling.

Time-Based Activity Analysis

The task narrative information was transferred to time-based data detailing the sensory and motor channels used in performance of each activity. The importance of this step is the provision for locating the high workload tasks. High workload is defined as a situation requiring speed and accuracy or time-sharing of activity between input and output channels.

Human performance studies have shown that there are certain tasks which can be time-shared well with other tasks. In general, these studies have shown that optimal performance, if tasks must be time-shared, will occur when the task demands (information channels) are divergent (Wickens, 1974; North, 1977). Conflicting demands (i.e., flying and manual data entry, speaking and listening) will produce degraded performance, while non-similar demands (flying and speaking, looking and listening) will have a much greater chance

TABLE 1. TASK NARRATIVE EXAMPLE

Mission Segment: Air Refueling
Time Frame: 0436

Pilot Tasks	Copilot Tasks	Additional Aircrew Tasks
Calls for preparation for contact checklist.	Reads preparation for contact checklist.	RN—Calls range to tanker in 1 NM increments. Calls range at 3 . . . 2 NM.
1. Establish radio contact		
	2. Check air conditioning system.	
		N—3. Set rendezvous radar to standby.
	4. Turn anticollision lights off.	
	5. Turn navigation lights to flash.	
6. Disengage autopilot.	6. Set slipway and airplane light switches to full bright.	
7. Set airbrake lever to position 1.	7. Open slipway doors and verify ready lights on.	
	8. Determine tanker position on FLIR sensor.	RN—8. Determine tanker position on FLIR sensor.
9. Select FLIR video.		
	10. Set air refueling switch to air refuel.	

of being performed well together (Kerr, 1973; Harris, North, and Owens, 1978). Table 2 summarizes human performance research findings on time-sharing performance. This chart was used to define the ranking of time-sharing difficulty for the B-52 mission. Manual flight control (VIS/MAN) and radio channel change (MAN/VIS) time-sharing would be categorized as "high difficulty," while flight control and listening to radio messages (AVD) would be categorized as "low difficulty."

In this analysis, we have divided each tasks's I/O channels into several categories. We have also dichotomized discrete tasks and continuous tasks because of the likelihood that speech tasks will be discrete. Because AST provides new ways to "multiplex" information to and from the crewmember, we must consider the potential benefit to performance during time-sharing periods when certain discrete tasks are changed to speech modes.

TABLE 2. MATRIX OF HUMAN TIME-SHARING DIFFICULTY

	VIS/MAN	VIS	MAN	AUD/VOC	AUD	VOC
VIS/MAN	High	---	---	---	---	---
VIS	Med	High	---	---	---	---
MAN	Med	Med	High	---	---	---
AUD/VOC	Low	Low	Low	High	---	---
AUD	Low	Low	Low	High	High	---
VOC	Low	Low	Low	High	Med	High

Three categories of time-sharing involvement were chosen to represent the potential interference among tasks. A "zero" ranking indicates that there is no continuous manual/visual task to compete with the discrete manual/visual task. A "one" indicates continuous visual monitoring/search with no manual task demand. A "two" indicates that the operator is engaged in a continuous visual/manual task. This last group includes the flight control involved in low-level penetration, air refueling, takeoff, and landing maneuvers.

A second categorization of all tasks is the anthropometric demand. To obtain this category, we divided the cockpit into regions. A "zero" category indicates that the task has no anthrompometric demands (e.g., a vocal task or listening task). A "one" category indicates that the task is within the central region, i.e., the central panel, on control yoke, within foveal vision, etc. A category of "two" or "three" indicates departure from this central zone (overhead panel, aisle stand, side panels). The cockpit regions for the three zones are shown in Figure 2. Anthropometric considerations become important in the choice of speech task candidates because of the potential that AST holds for removing certain tasks from the manual-visual modalities. If the crewmembers can perform these tasks without diverting attention from the central panel or outside world by adding speech technology, the switch to AST would be beneficial. It is helpful to categorize various avionics devices into these zones for later reference. Figure 3 shows this breakdown with the major functional involvement by the pilot or copilot by cockpit areas.

A third category appearing on these task lists is information retrieval. This category was added to our list in light of pilot interviews. Many tasks on the B-52 require the retrieval of information in the flight manuals. This includes performance charts, emergency checklists, departure plates, and other material that is not usually kept in human memory. Retrieval from this data bank occurs several times during an average flight.

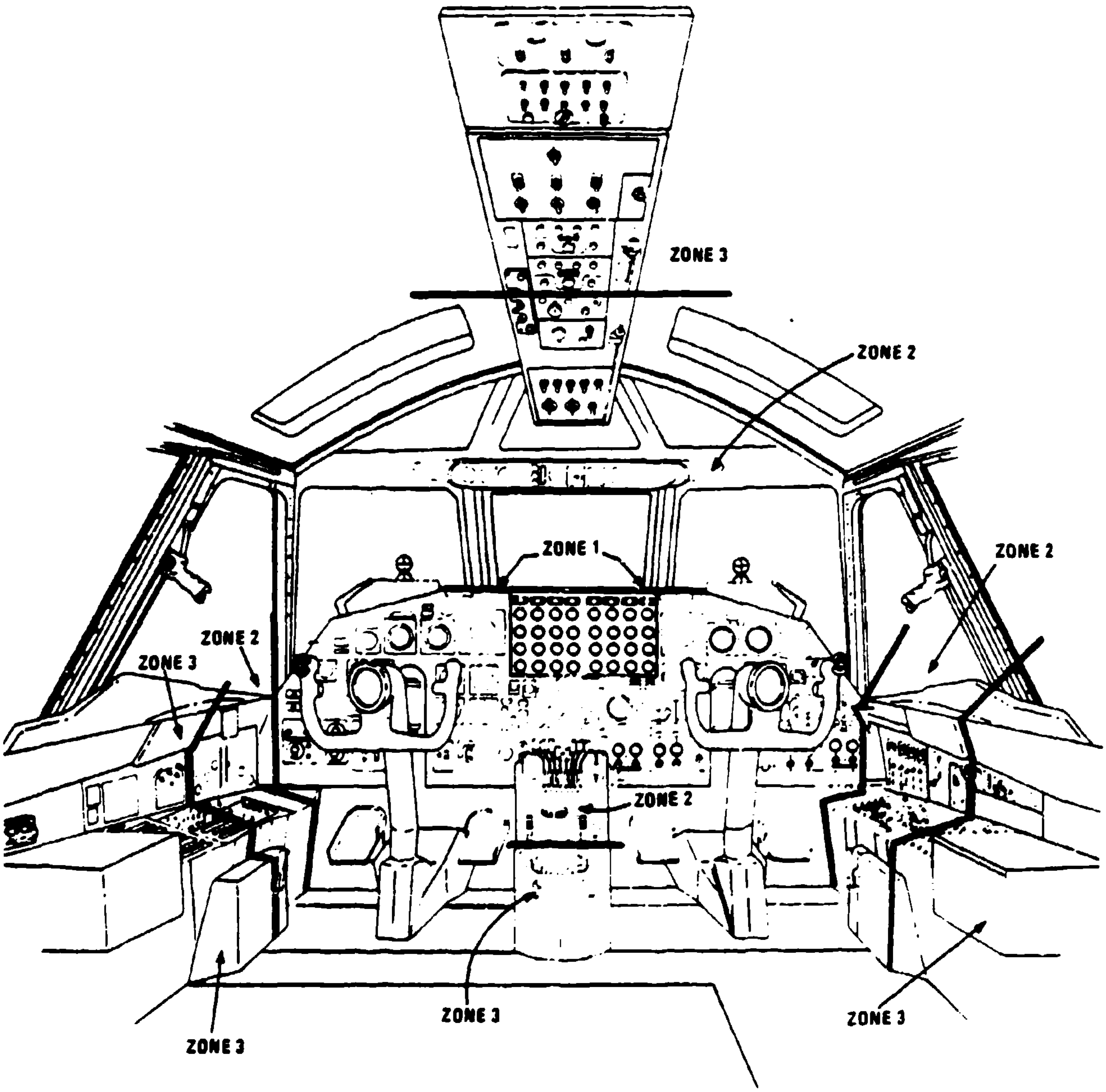

Figure 2. Anthropometric Zones

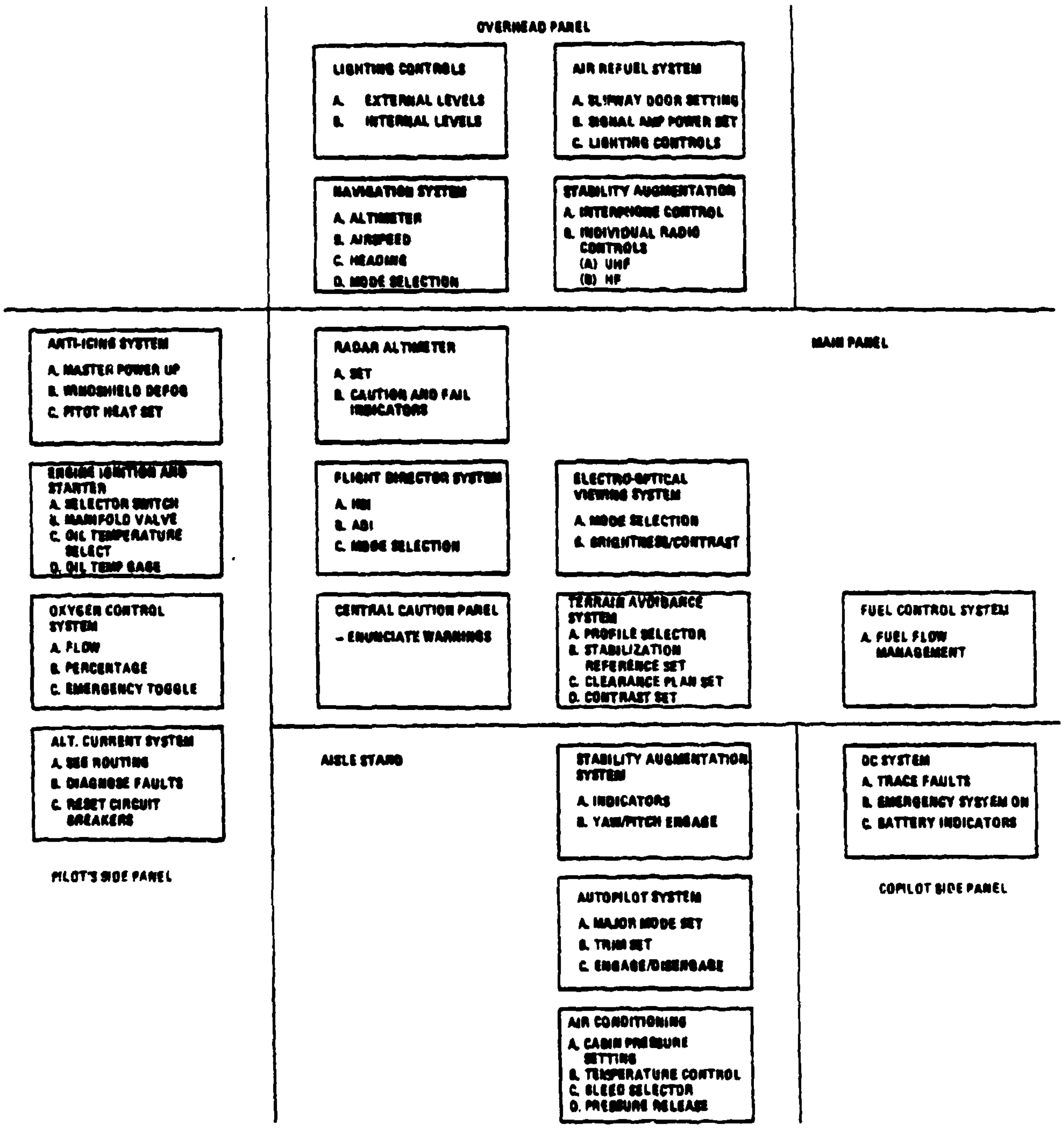

Figure 3. Breakdown of Avionics Devices by Cockpit Areas

Activity Logs

Task narratives were transferred to time-based activity logs (Appendix B) which contain a breakdown of all discrete task actions performed by the pilot or copilot. The main task descriptions discussed in the previous section were used to classify activities. All communications activities have been added to this log.

Time-Based Activity Charts

A summary of our task analysis is depicted in the time-based activity charts for each mission segment (Figures 4 to 7). In these charts, we have dichotomized all tasks into discrete and continuous tasks. Modalities of operation for each event are shown under the appropriate columns. The key to these modality abbreviations is:

Vi, VIS = visual input	M, MAN = manual output
A = auditory input	Vo = vocal output.

For each discrete event, we have shown two categories for input and output requirements. Some events or tasks do not require both input and output (e.g., listening to a radio transmission). Input was divided into visual and auditory channels; output was divided into manual and vocal categories. Mission sub-segments are indicated in the right margin of the charts. Continuous task requirements are divided into the visual and manual categories, and include the flight control and exterior monitoring tasks as well as the instrument scan and crosschecks.

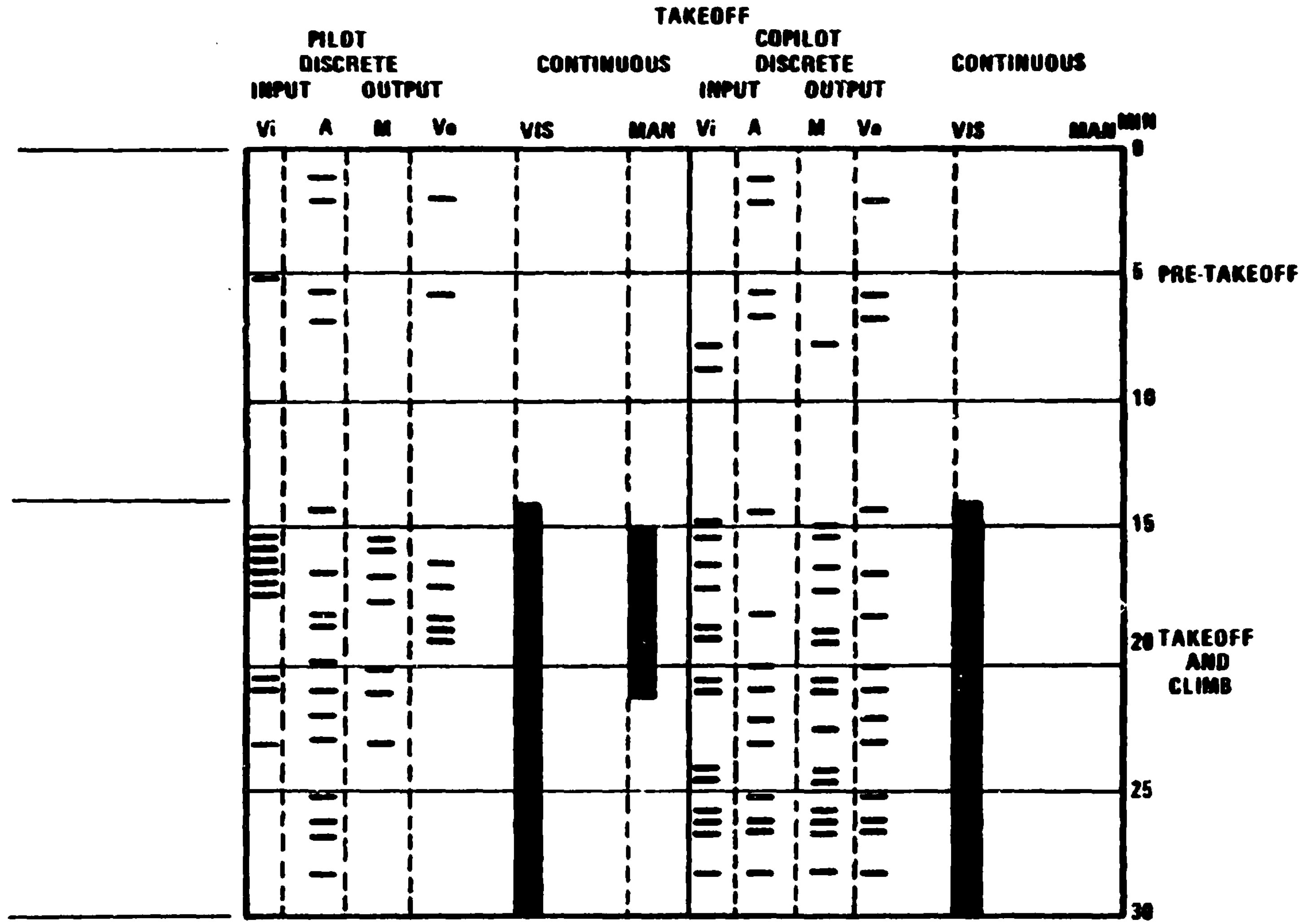

Figure 4. Takeoff Activity Chart

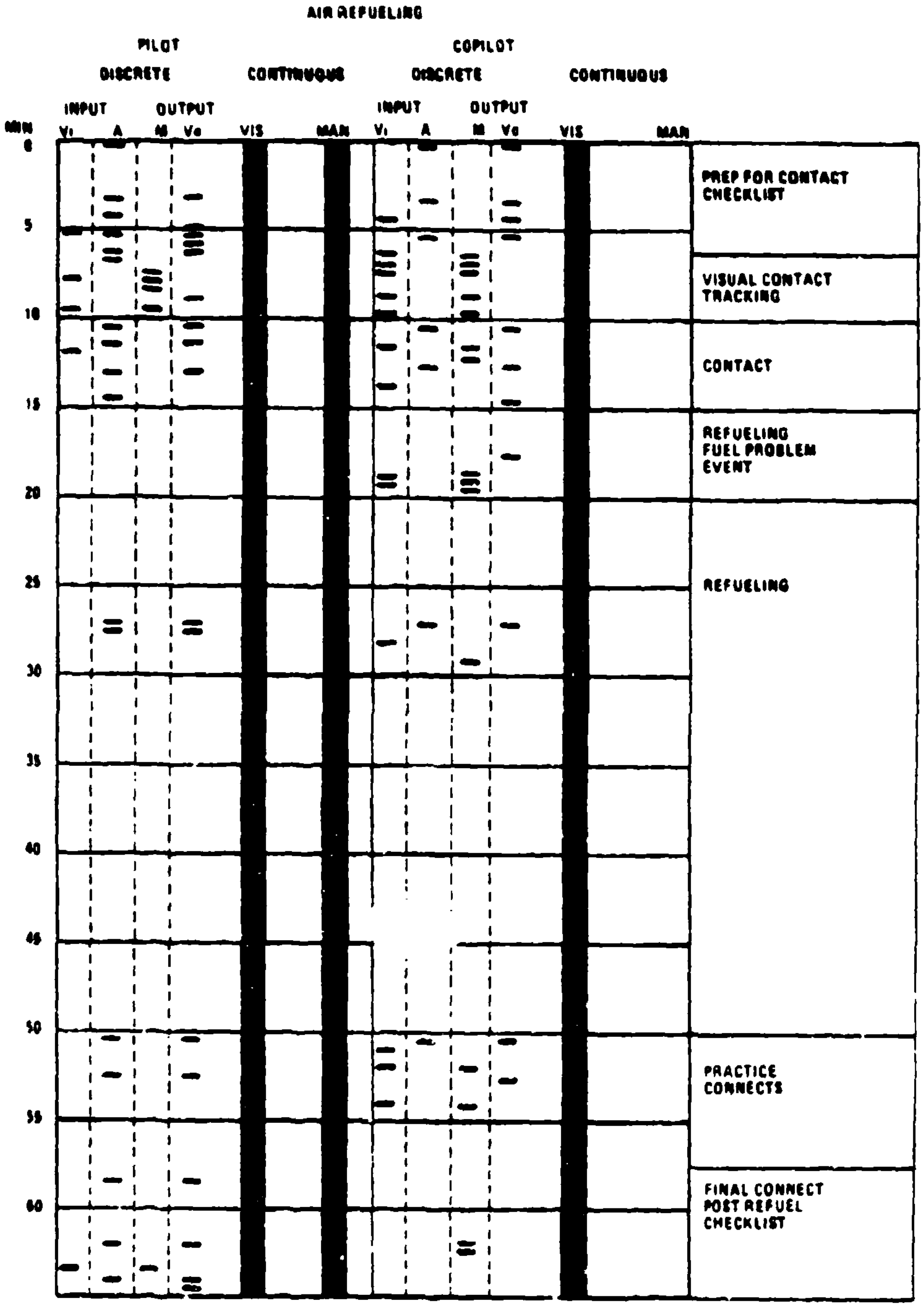

Figure 5. Air Refueling Activity Chart

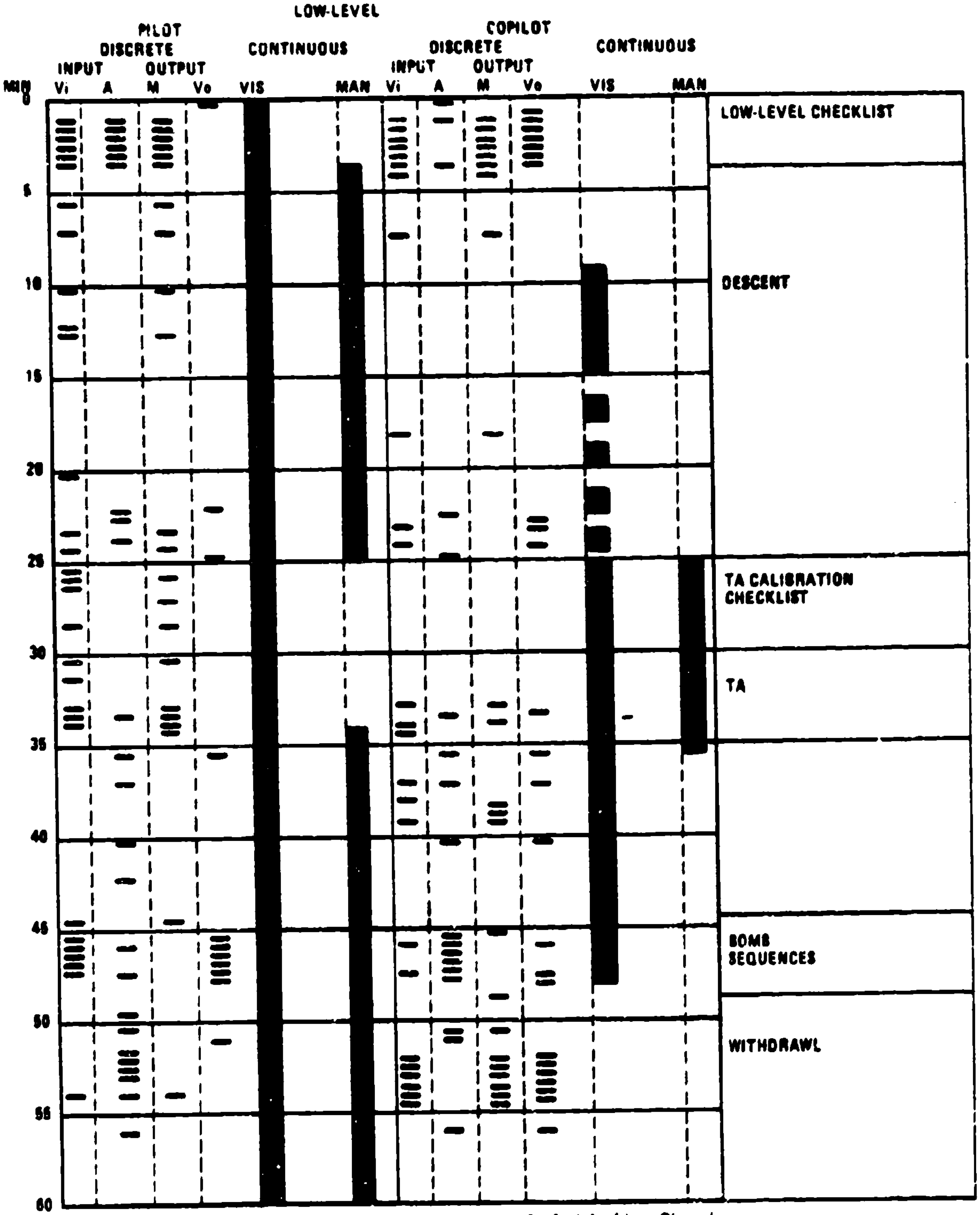

Figure 6. Low Level Activity Chart

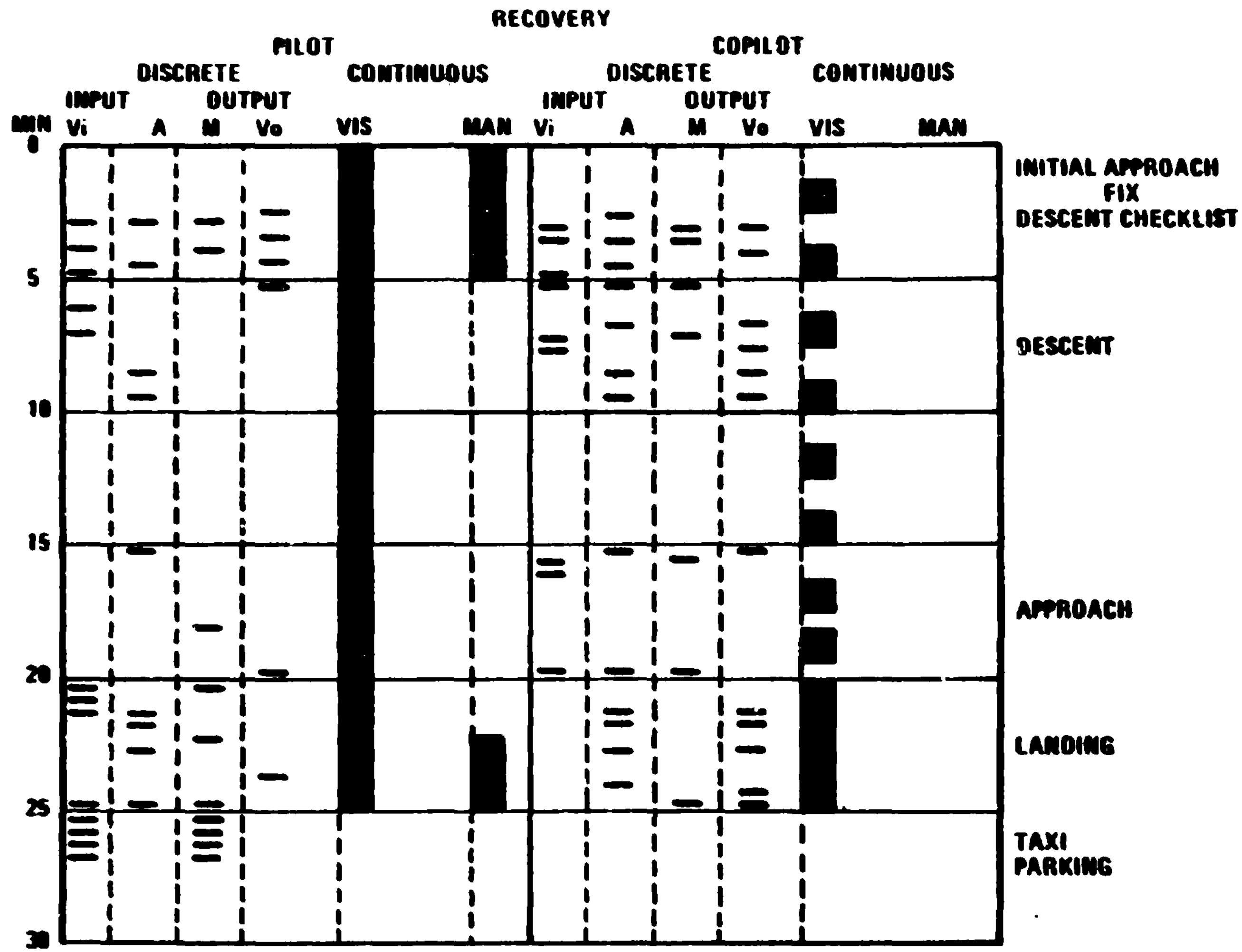

Figure 7. Recovery Activity Chart

Choosing the AST Tasks

Initial Filtering Criteria--Not all of the tasks documented in the task narrative lists will be suitable for AST implementation. Therefore, some initial screening criteria need to be applied to reduce the list to the most cost-effective set. We have summarized these criteria in decision charts in Figures 8 and 9. Although other criteria could include system constraints, cost to implement, etc., we have restricted these criteria to include only human engineering factors at this stage. The technological issues will be considered at the task rating stage of analysis.

Speech Recognition Criteria--For voice recognition, the most likely filter is whether the task is discrete or continuous action. Human control of the speech channel is geared for the production of discrete utterances and does not lend itself to continuous control. Although some continuous control tasks may be performed by a series of discrete actions (e.g., "bang bang" tracking control tasks), these tasks are rare in the aircraft cockpit. Our initial screening filter for speech recognition tasks, therefore, is allowance of only discrete tasks to enter the list.

A second filter concerns the frequency of the activity. We do not want to add tasks to the speech system which occur a limited number of times during the mission. We have arbitrarily selected three as this number of events. Of course, this filter should be tempered by the criticality of the function provided by the voice vs the manual tradeoff involved. If voice input will provide a critical savings in concurrent task performance, consideration should be given to its inclusion.

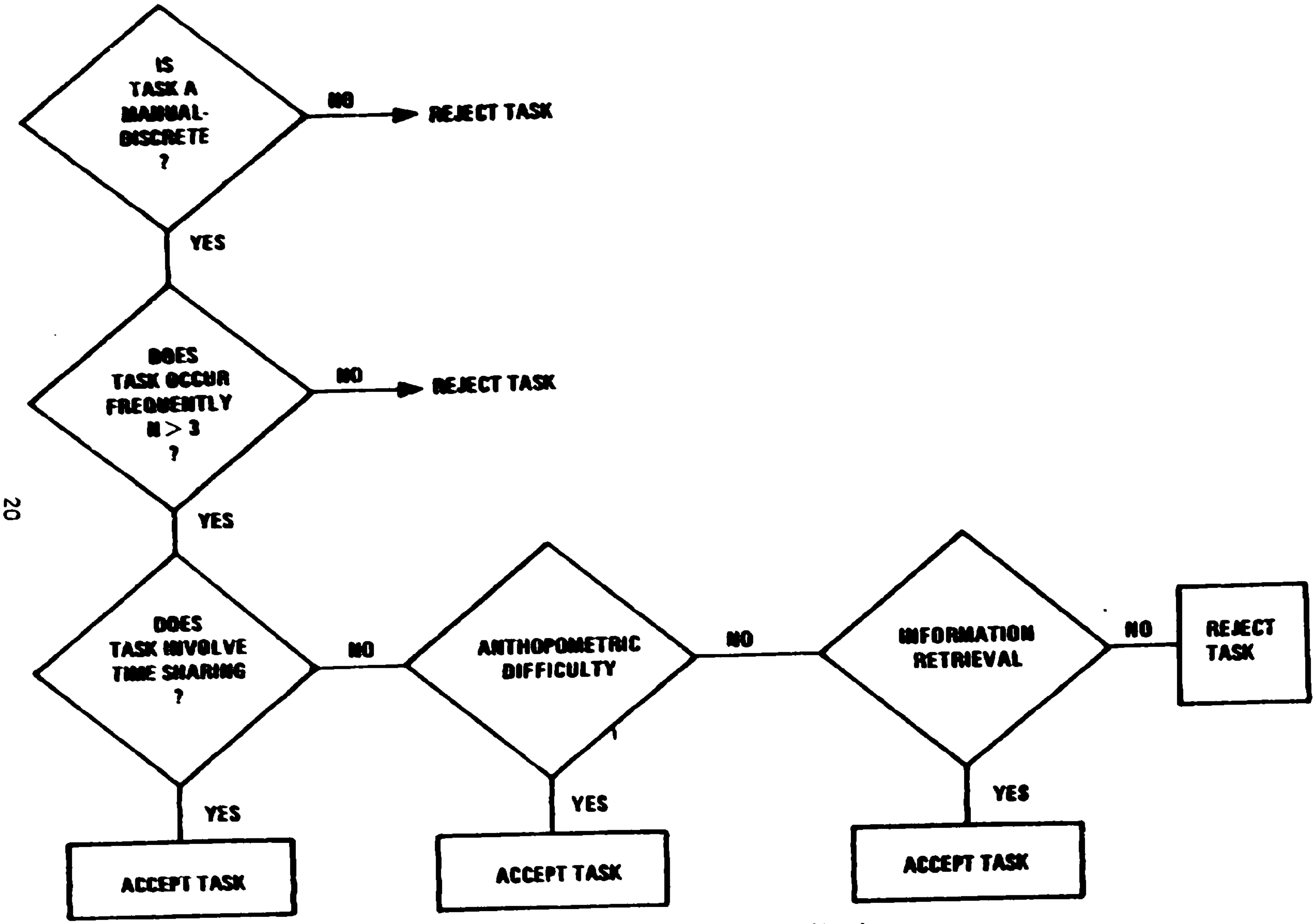

Figure 8. Speech Recognition Criteria

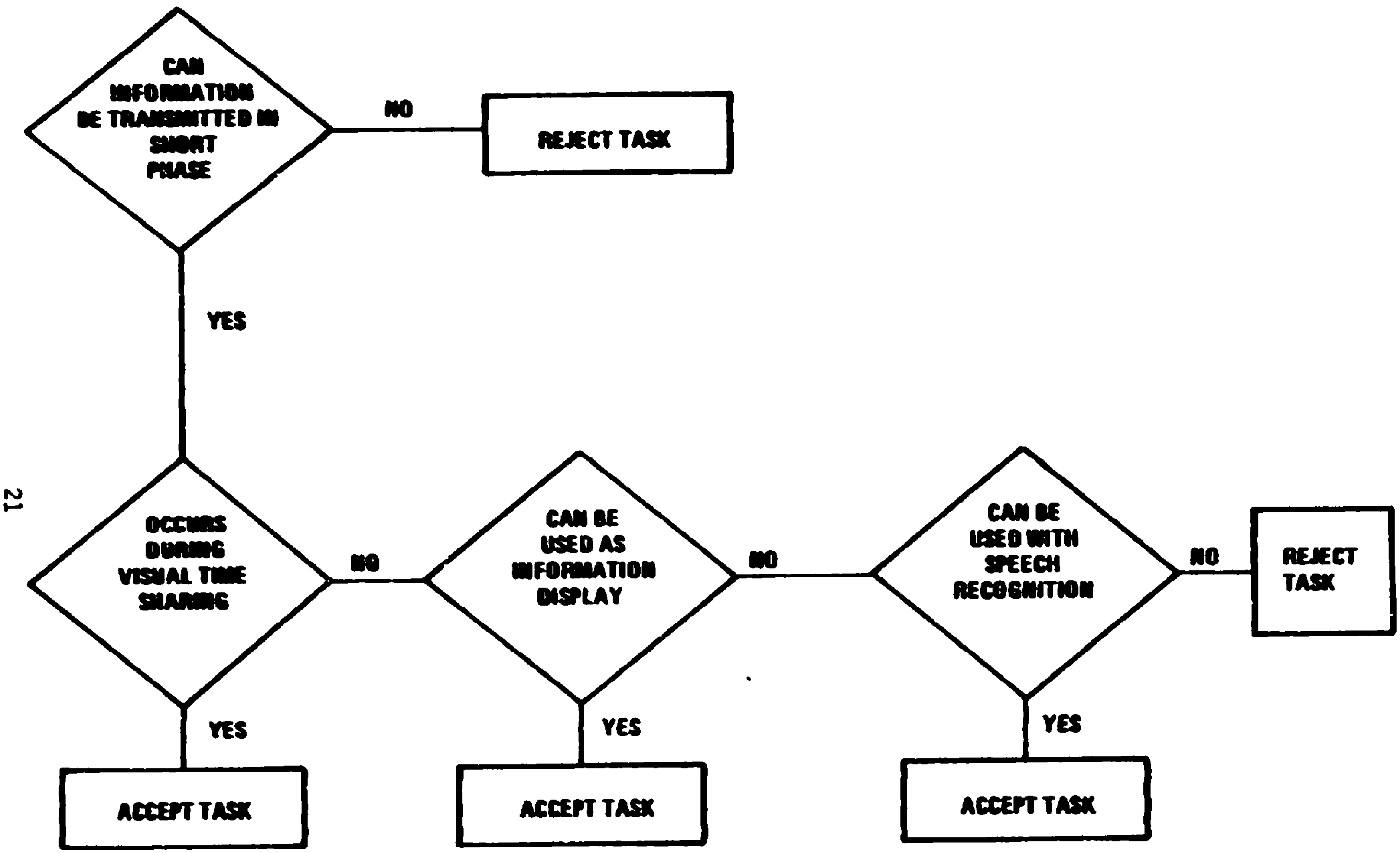

Figure 9. Speech Generation Criteria

Three other criteria provide quantitative ratings for each task candidate. These are whether the task: 1) occurs during a time-sharing load; 2) is outside the primary reach zone; or 3) requires information retrieval. Provided the task contained one of these elements and passed the first two criteria, it was advanced to the candidate list.

Speech Generation Criteria--For speech output, our initial filter was length of message. We have limited ourselves to situations that lend themselves to short transmissions or phrases. This is compatible with the storage limitation of the anticipated hardware and with the functional problem of overloading the auditory channel in the cockpit. Pilot interviews revealed a strong desire to keep the auditory channel free of verbosity.

Three conditional filters were also used to screen speech generation tasks. The task was promoted to AST candidate status if: 1) it occurred during visual time-sharing; 2) it could serve as an information display that currently does not occur in the central anthropometric visual zone; or 3) it could be used together with speech recognition in an interactive dialogue format.

AST Candidates

Table 3 presents all tasks passing the necessary criteria for speech recognition task candidates. Table 4 presents speech generation candidates. These charts reflect the anticipated usage of each AST task candidate by mission segment. Some tasks may occur outside the indicated mission segments, however. The "All Segments" group indicates no specific assignment of this task in time; e.g., the task may occur any time during a flight.

TABLE 3. SPEECH RECOGNITION TASKS

TAKEOFF/LANDING MISSION SEGMENT
Radio Frequency Changes
Altimeter Settings
Nav System Control (Flight Director)
IFF Mode Selection
Air Conditioning Control
Fuel Panel Control
Steering Ratio Select
AIR-REFUELING MISSION SEGMENT
Refueling Panel Control
Anti-Collision Lights
Signal Amp Button Reset
Video System Control
LOW LEVEL BOMBING MISSION SEGMENT
Clearance Plane Control
Radar Altimeter Cursor Set
Terraine Display Control
Recordkeeping in TA
Set Heading in HSI
Bleed Selector Control
Start/Stop Timer
ALL SEGMENTS
Chart Retrieval
Checklist/Emergency Procedures Retrieval

TABLE 4. SPEECH GENERATION TASKS

TAKEOFF/LANDING MISSION SEGMENTS
Altitude Calls
Airspeed Calls
Flaps Position
AIR REFUELING MISSION SEGMENT
Slant Range Calls
Contact/Disconnect Calls
LOW LEVEL MISSION SEGMENT
"TO-GO" Calls (seconds)
Bleed Select Status
ALL MISSION SEGMENTS
Master Caution Panel
Circuit Breaker Status

SECTION 3

AST CANDIDATE RANKING

PILOT UTILITY

Objective Ranking Procedures

Each task was ranked on a set of objective criteria produced by the task analysis phase. Four indices were used to produce a final total ranking score: 1) information retrieval; 2) time-sharing index; 3) anthropometric difficulty; and 4) communications disruption. The first three of these have been previously discussed in terms of our task analysis. The communications disruption index was added to adjust the ranking of speech tasks that could potentially interfere with ongoing communications. The time activity analysis was used to compare the "before" and "after" effect of changing all task candidates to the speech modalities (see Figures 10 to 13).

We have summarized the data represented in these charts in tabular form by totals for each pilot/copilot modality. For the discrete tasks we have totalled the number of occurences of manual, vocal, auditory, and visual task events. Table 5 shows these totals by mission segment. These data indicate that the addition of AST would:

- Greatly reduce the total number of manual discrete events in all segments except recovery.
- Greatly increase the number of vocal responses required by both crew members.
- Partially reduce the visual discrete events.

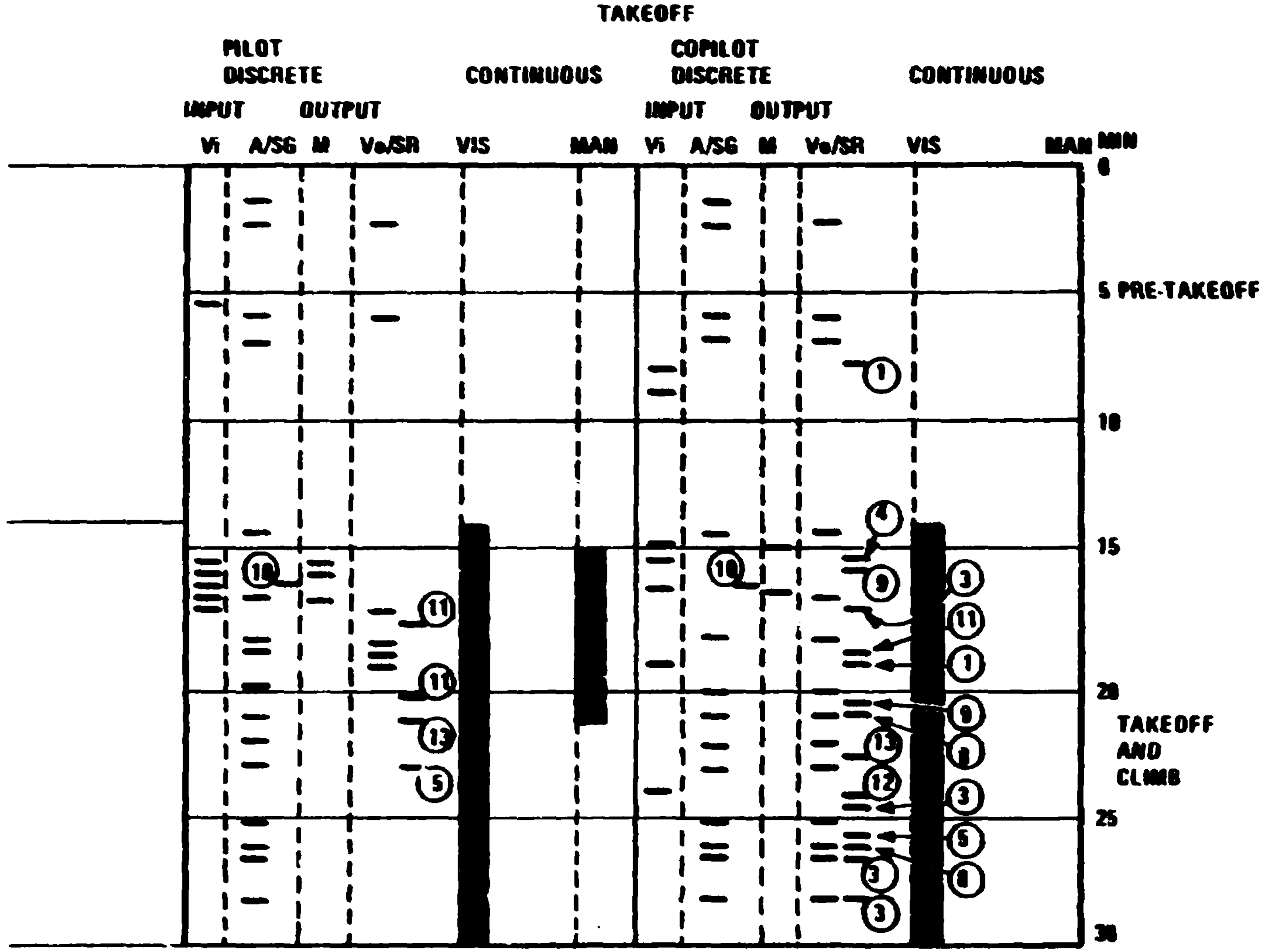

Figure 10. Takeoff Activity with Speech Recognition (SR) and Speech Generation (SG) Candidate Tasks

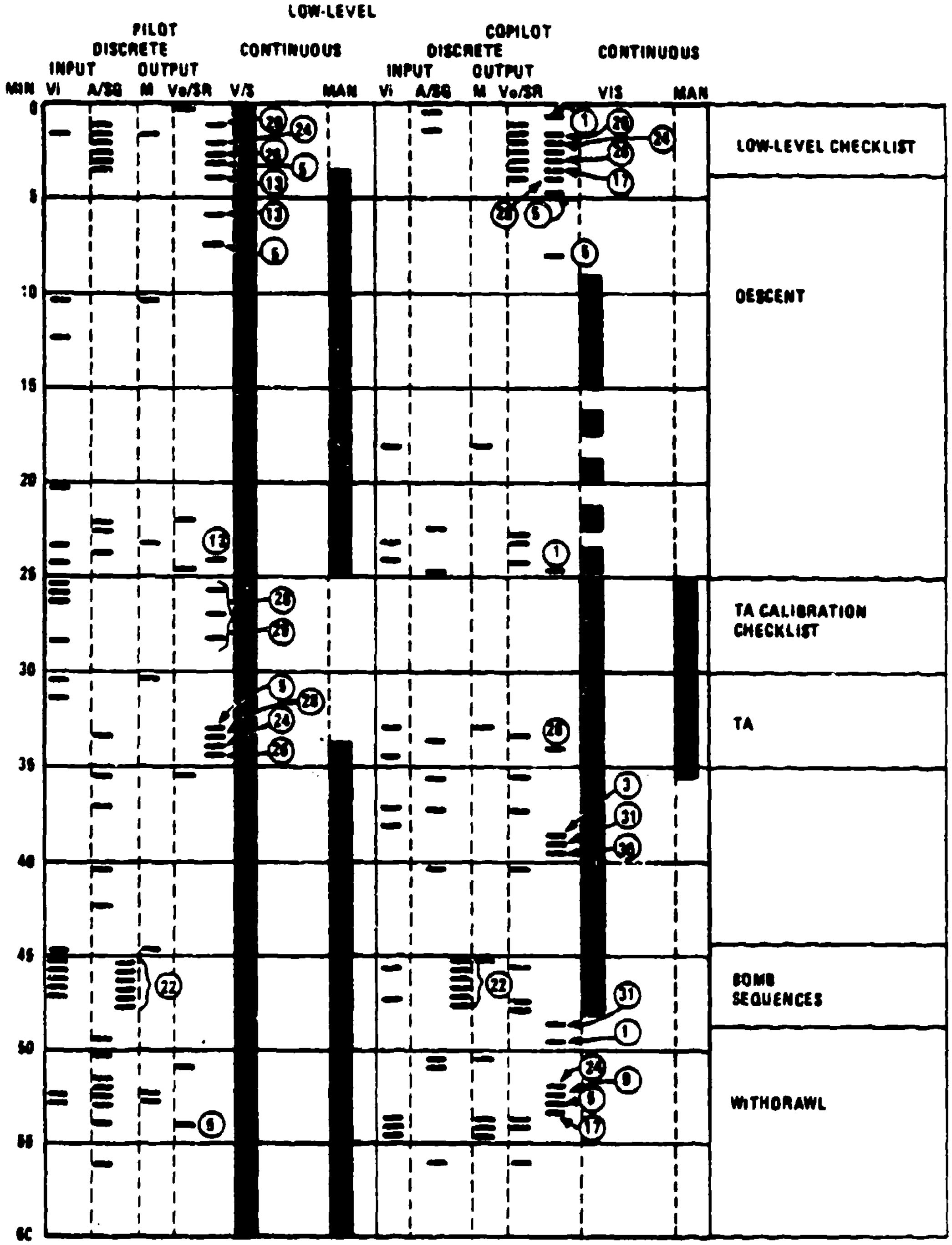

Figure 11. Low Level Activity with Speech Recognition (SR) and Speech Generation (SG) Candidate Tasks

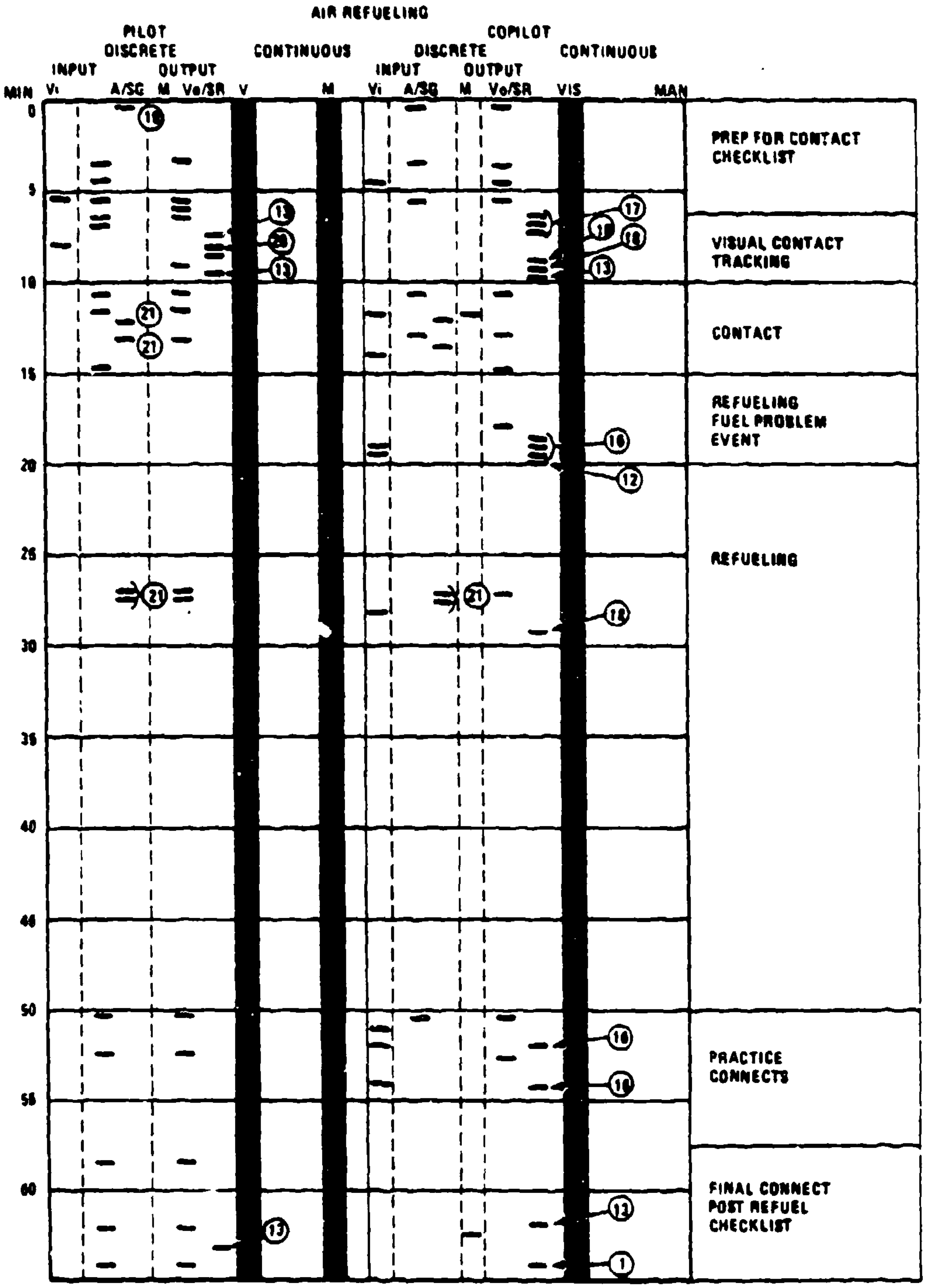

Figure 12. Air Refueling Activity with Speech Recognition (SR) and Speech Generation (SG) Candidate Tasks

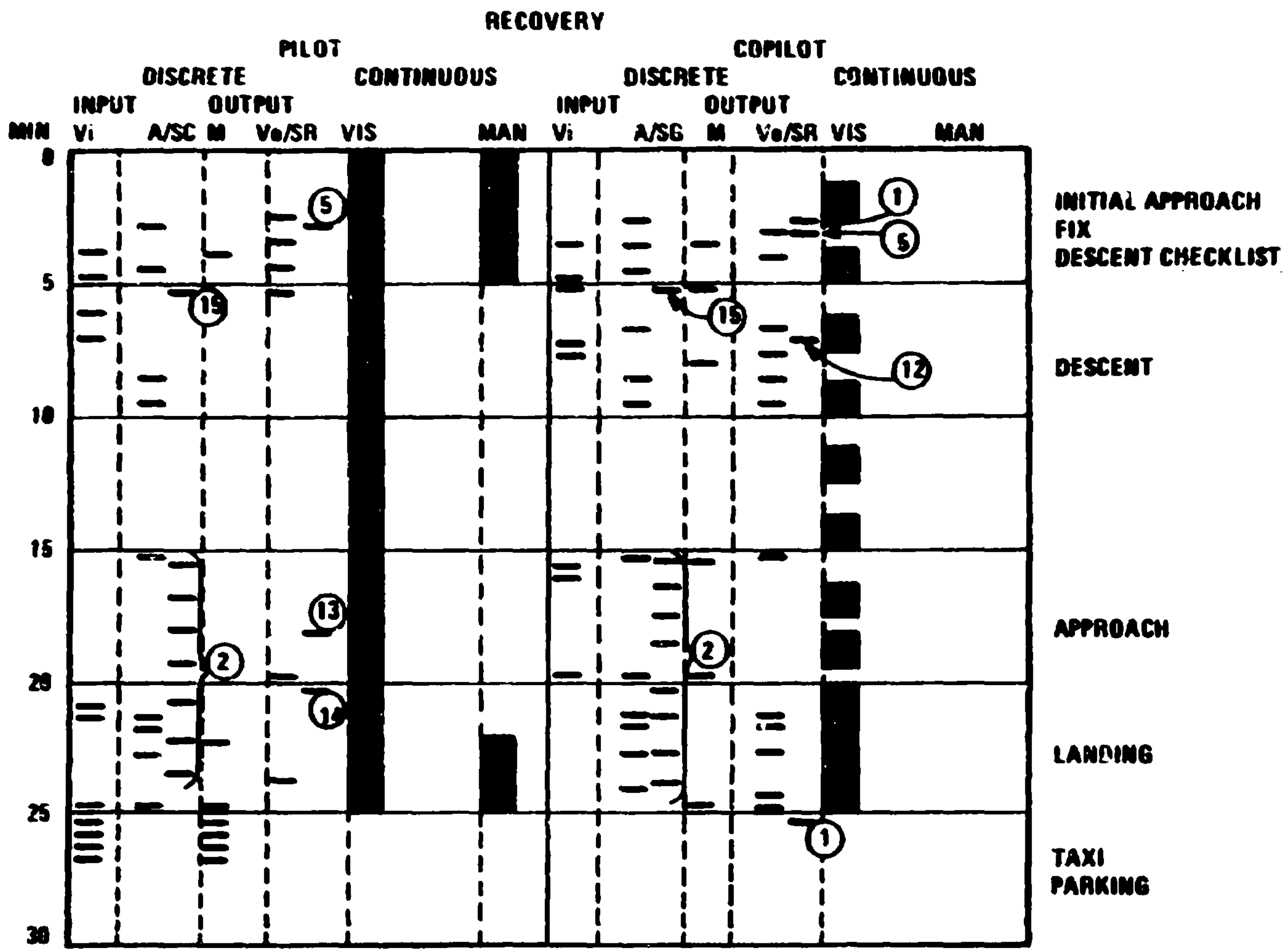

Figure 13. Takeoff Activity with Speech Recognition (SR) and Speech Generation (SG) Candidate Tasks

TABLE 5. DISCRETE EVENTS MODALITY SUMMARY BEFORE AND AFTER AST IMPLEMENTATION

	Takeoff		Refuel		Low Level		Recovery		Total		% Change
	No AST	With AST	No AST	With AST	No AST	With AST	No AST	With AST	No AST	With AST	
COPILOT											
Manual	16	2	15	2	23	7	7	6	61	17	-72.1
Vocal	14	29	11	25	24	40	12	16	61	110	+80.3
Visual	16	7	14	9	25	12	9	8	64	36	-43.8
Auditory	14	15	7	10	18	17	13	21	52	63	+21.2
PILOT											
Manual	7	3	5	0	22	7	10	7	26	17	-34.6
Vocal	7	10	17	20	11	21	6	9	41	60	-46.3
Visual	10	6	5	2	32	20	13	11	60	39	-35.0
Auditory	16	17	17	18	24	22	9	17	66	74	+12.1

- o Keep the auditory events at the same level except during recovery.
- o Appear to reduce the total number of discrete events in some segments while adding events in others.

We shall discuss each of these points in more detail in the discussion and conclusions in Section 6.

<u>Pilot Ratings</u>--A group of eight B-52 G/H instructor pilots (IPs) were given a questionnaire assessing their perceived utility for changing each AST candidate task to speech. The questionnaire was presented in a six-point ranking format. The tasks were presented with examples of potential implementations to facilitate understanding of a speech system's capability. An example of this format is presented here. The complete questionnaire is presented in Appendix C.

Example of Questionnaire Element

During Takeoff or Recovery, if you could call up a checklist (and display it on the EVS) by voice command

Example: "Descent Checklist"

	1	2	3	4	5	6	
Never Useful	____	____	____	____	____	____	Always Very Useful
			Sometimes Useful				

The scoring procedure involved computing a mean utility rating for each task. A "six" would indicate the top score possible, e.g., maximum utility from converting this task to the appropriate speech technology.

Pilot Utility Ratings for AST Candidates

The ratings for both objective (Task Analysis) and subjective (Pilot Questionnaires) ranking methods were normalized to provide a basis for a final combination of rating schema. The raw score rankings and their normalized scores are presented in Tables 6 and 7 for recognition and generation, respectively.

There was good correspondence between the objective and subjective ranking methods in this analysis. The overall correlation for all tasks (N=31) between these scoring procedures was 0.67.

Weighted Rating Scheme--Discussions with pilots indicated that reducing the time-sharing (TS) and information retrieval (IR) workloads were more important than reducing anthropometric difficulty (AD) in the cockpit. Therefore, we assigned a heavier weighting to these scales than to anthropometry. The weights for these ratings were:

Utility Rating: 2 x IR + 2 x TS + 1 x AD - 1 x CD.

The communication disruptive (CD) score was derived from categorizing the potential disrupting influence of switching to speech technology for a given task. If the speech input/output fell within one minute of scheduled communications, it was scored as a "two." Speech candidates falling within five minutes were given a "one," and tasks outside this range were given a "zero" disruption index. This time-dependent ranking scheme was chosen as an estimate of the probability of disruption only. It is likely that variability across missions would influence the temporal proximity of events.

TABLE 6. SPEECH RECOGNITION TASK PILOT UTILITY RATINGS

Task	Utility						
	Objective Scores					Subj. Score	Combined Rating*
	IR	TS	AN	CD	(T)		
Takeoff/Landing Mission Segment							
3 Radio Frequency Changes	1	2	3	2	(7)	5.38	+2.01
5 Altimeter Settings	0	2	1	1	(4)	4.50	-0.14
7 Chart Retrieval	2	2	3	1	(10)	6.00	+3.91
8 IFF Mode Selection	0	2	2	2	(4)	5.38	+0.74
9 Air Conditioning Control	0	0	2	1	(1)	3.00	-2.92
11 Navigation System	0	2	2	1	(5)	4.50	+0.28
12 Fuel Panel Control	0	1	1	1	(2)	3.63	-1.87
13 Autopilot Control	0	2	3	1	(6)	3.13	-0.66
14 Steering Ratio Select	0	0	2[s]	1	(0)	2.25	-4.09
1 Checklist/Emergency Recall	2	2	2	1	(9)	5.38	+2.87
Air-Refueling Mission Segment							
16 Refueling Panel Control	0	0	1	0	(1)	3.38	-2.54
17 Anti-Collision Lights	0	0	2	1	(1)	3.13	-2.79
18 Signal Amp Button Reset	0	0	2[s]	0	(1)	4.88	-1.04
20 Video System Control	0	2	1[s]	1	(3.5)	3.75	-1.10
Low-Level Bombing Mission Segment							
24 Clearance Plane Control	0	2	3	1	(6)	4.88	+1.09
26 Radar Altimeter Cursor Set	0	2	1	1	(4)	4.60	-0.04
28 Terrain Display Control	0	2	3	1	(6)	5.88	+2.09
29 Record Keeping in TA	1	1	1	0	(5)	5.00	+0.78
30 Set Heading in HSI	0	2	2	0	(6)	5.38	+1.59
23 Bleed Selector Control	0	2	2[s]	0	(5)	2.75	-1.46
31 Start/Stop Timer	0	2	0	0	(4)	4.50	-0.14

*Combined Rating is the sum of normalized scores for the objective and subjective ratings, and was used only to rank order tasks on the utility scale.

[s]Simple switch position change.

TABLE 7. SPEECH GENERATION TASK PILOT UTILITY RATINGS

	Utility						
	Objective Scores						
Task	IR	TS	AN	CD	(T)	Subj. Score	Combined Rating*
Takeoff/Landing Mission Segment							
2 Altitude Calls	0	2	1	1	(4)	4.88	+0.24
10 Airspeed Calls	0	2	1	1	(5)	4.00	-0.22
15 Flaps Position	0	2	2	0	(6)	5.75	+1.96
Air Refueling Mission Segment							
19 Slant Range Calls	0	1	0	0	(2)	4.50	-0.99
21 Contact/Disconnect Calls	0	2	1	0	(5)	3.75	-0.47
Low Level Mission Segment							
22 "TO-GO" Calls	0	2	0	0	(4)	4.60	-0.04
23 Bleed Select Status	0	2	2[a]	0	(5)	2.80	-1.46
All Mission Segments							
4 Master Caution Panel	0	2	1	1	(4)	5.00	+0.36
32 Circuit Breaker Status	0	2	4	1	(7)	6.00	+2.64

*Combined Rating is the sum of normalized scores for the objective and subjective ratings.

TECHNOLOGICAL FEASIBILITY OF AST CANDIDATE TASKS

AST Candidate Task Descriptions

As a prerequisite to technological feasibility rankings, we have suggested a potential implementation scheme for each of the recognition/generation tasks. These schemes, required for the technological feasibility rankings, provide a framework for demonstrating the concepts to the users in the briefings described in Section 5.

Assumptions

We made several assumptions in creating these implementation schemes for each task. First, we assumed that these tasks could be handled by either isolated-word recognizers (IWR) or connected-word recognizers (CWR) without significant human factors problems. Connected speech was not found to be necessary for most of these tasks, and interviewed pilots revealed a definite preference for short verbal comands to any on-board recognition device to avoid conflicts with the interphone communications and radio procedures. We have provided schema for both IWR and CWR potential formats, however.

A second assumption affecting task implementation was the method of feedback of information to the pilot or copilot during a recognition task. We assume much heavier use of the EVS display for alphanumerics, e.g., use of the EVS as a temporary scratchpad area, verification of recognition (feedback), and display of information that has been recalled. A second means of feedback would be via speech generation, presumably linked into the interphone headsets.

A further assumption that impacts implementation is the need for certain syntactical rules during a transaction. This was more of a necessity for some tasks than others due to the variation of task complexity. Following the trend of the use of syntax structuring for most recognition systems today (even for connected speech systems such as HARPY and HEARSAY), we present examples of the expected syntax structure for the appropriate tasks. These syntax structures can significantly increase recognizer performance by reducing the number of vocabulary items which are "valid" at any one time. The complete set of recognition/generation task example formats appears in Appendices D and E. We have provided one example of each type on pages 37 and 38. We have also included a "combination task" using both technologies in a dialog format on page 39.

Technological Feasibility Scaling--Recognition Tasks

In the absence of a full theory of feasibility assessment, we will take a straightforward, simplistic approach to assessing the technological feasibility of our AST candidates. We will assume that if we can find where on the spectrum of feasibilities the required recognition capability for each task is to be found, we will assign that general recognition feasibility to be that task's feasibility rating. It will be crucial, since most of the selected tasks assume isolated words under moderate noise conditions, to assess the confusability of the vocabulary required for each task. Tasks will be preferred that require only a very simple vocabulary. One variant in such judgments will be the fact that we could revise the potential vocabulary for each task by removing confusable words and replacing them with easily-distinguished synonyms. While a minimal number of such changes will be considered, we will assume that the vocabularies suggested will in most cases be used and assessed, as given, without revisions.

CIRCUIT BREAKER STATUS (Sample Recognition Task)

Many of the circuit breakers are located in a remote position from the forward stations. The incidental "pop" of a circuit breaker can go undetected, and the pilot or copilot must request the gunner to check for certain breaker status.

VOCABULARY CONTENT: Digits, Breaker, Out

Implementation:

CWR: P--"What is status of breaker twenty-four?

SG--"Twenty-four breaker out."

IWR: P--"Breaker status--two--four."

CONTACT-DISCONNECT CALLS DURING AIR REFUELING
(Sample Generation Task)

Air refueling conditions could be enunciated via voice generation. These conditions are presently indicated by a lighting system on the eyebrow panel.

VOCABULARY CONTENT: Ready for Contact, Contact Made, Disconnect

RECORD KEEPING IN TA CALIBRATION (Sample Recognition/Generation Task)

Performed by pilot during entry into low levels. Requires pilot to switch between worksheet, visual displays, and outside world. AST was judged useful for application in this task by pilots. Could be especially useful for "on-line" computational work.

VOCABULARY CONTENT:

First Node: Error Type, Compensation, Compute

Second Node: (Error) complete dropout, partial dropout, side dropout, weather effects, bias errors, tilt errors, tile and bias; (Compensation) peak tilt, peak bias, flat roll bias, flat roll tile; (Compute) digits

Implementation:

IWR: "TA CAL--error type--partial drop-out"

CWR: "TA partial drop-out error"

SG: (Prompts each entry)

Feasibility Factors to Consider as Most Important

Feasibility is primarily determined by the form of speech, the noise conditions, and the confusability of the vocabulary needed for each task. We have seen that the most feasible recognition tasks involve isolated word recognition or recognition of simple, connected word sequences. All the tasks selected are amenable to such simple recognition methods. Thus, we need not consider the form of speech, other than assessing the feasibility of two distinct options (wherever both could reasonably apply): recognition of isolated words, or recognition of simple word sequences. Feasibility of each option will thus be almost entirely determined by the vocabulary confusability assessment.

Once we have an assessment of feasibility based on vocabularies, we can integrate the effect of noise almost as an independent after-thought or correction filter. The tasks with the highest-filtered feasibility scores will then be selected for earliest consideration as suitable speech recognition tasks.

Ultimately, it should be possible to assess the confusability of vocabularies by determining the "distance" between pronunciations of each pair of words and defining the confusability of the vocabulary as a function of such distances. It should be the case that such a measure gives most attention to words that are closest in sound structure, so that the most confusable words add the most to the assessment of vocabulary confusability. Such a comprehensive assessment of vocabulary confusabilities is fortunately not required for this project, and the scaling methodology outlined below permits us to assign a feasibility rating--provided we can determine whether each vocabulary is "simple," "moderate," or "difficult" to recognize. Such a judgment can be made for isolated word recognition and for connected speech recognition. Figure 14 summarizes the steps discussed above.

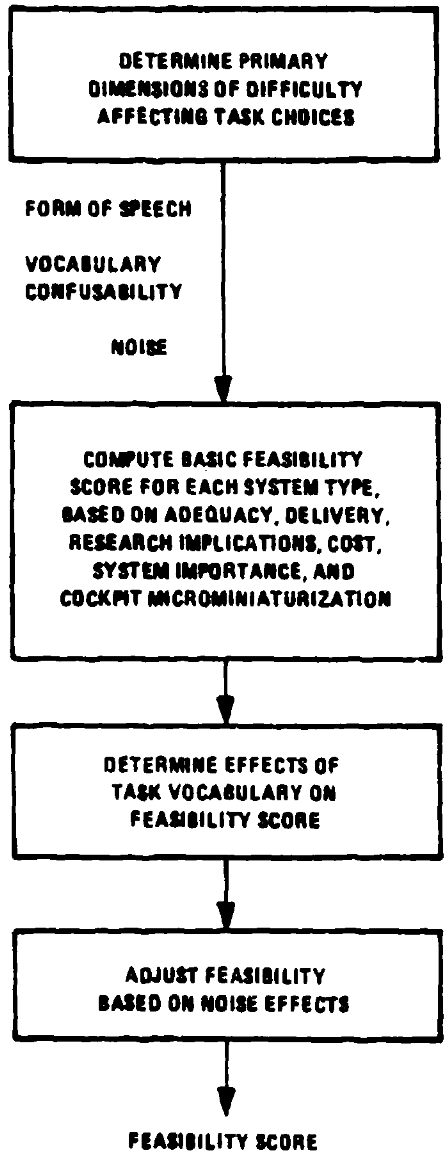

Figure 14. Steps in Determining the Technological Feasibility of Airborne Speech Recognition Tasks

Feasibility Assessments

Confusability--In lieu of laboratory determination or a rigorous procedure for assigning vocabulary confusion, we used a simple scheme to determine the ranks of simple, medium, or highly difficult vocabularies. This scheme was:

- o Simple: Digits.
- o Medium: Typical Flight Vocabulary.
- o Difficult: Alphabet, Letters (not phonetic alphabet).

We of course paid attention to potential confusions in each vocabulary's sound structure.

The vocabularies for most of the AST candidates were "simple," but a few were judged moderately difficult due to similar sound structures. Table 8 shows the list of recognition tasks, the gross judgments of vocabulary confusability, and a plot of associated feasibility ratings. Notice that a few tasks had vocabularies whose difficulty was judged borderline, between simple and moderate. Some of them could be simplified by changing some words to eliminate similar pairs of words. Especially suitable for such change would be utterances which have most portions identical, but that differ in only a local part of the utterance, such as "Profile 3" vs "Profile 10," or "Code A" vs "Code B," or "Pre-Takeoff" vs "After-Takeoff" vs "After loading." For such utterances, borderline vocabularies halfway between "simple" and "moderate" vocabularies were selected. We thus have only three distinguished feasibility "levels" assigned to the isolated word recognition approach to all the selected tasks.

TABLE 8. FEASIBILITIES OF USING VOICE INPUT IN SPECIFIC PILOT/COPILOT TASKS OF B-52H AIRCRAFT

		IWR Configuration			CWR Configuration
	Vocab.	Basic Score	Noise Effects	Net Feas. Score	Basic CWR - Noise - To/L Noise = Net
Takeoff and Landing Tasks					
? IFF Mode/Code Set	S/M	65	-2 -3	60	41 - 5 - 4 = 32
(*) Steering Ratio Selector	S	70	-0 -3	67	50 - 5 - 4 = 41
? Navigation System	S/M	65	-2 -3	60	41 - 5 - 4 = 32
(*) Set Altimeter	S	70	-0 -3	67	50 - 5 - 4 = 41
Change Radio Frequencies	M	65	-2 -3	60	41 - 5 - 4 = 32
Air Refueling Tasks					
Air Refuel Panel	M	60	-5	55	32 - 5 = 27
* Lighting Controls	S	70	-0	70	50 - 5 = 45
Low Level Tasks					
* Bleed Selector Switch Check	S	70	-0	70	50 - 5 = 45
* Record Keeping, TA/TF	M	60	-5	55	32 - 5 = 27
? Terrain Display Control	S/M	65	-2	63	41 - 5 = 36
* Radar Altimeter Cursor	S	70	-0	70	50 - 5 = 45
* Start/Stop Timer, Bomb	S	70	-0	70	50 - 5 = 45
All-Mission-Segment Tasks					
* EVS Control	S	70	-0	70	50 - 5 = 45
* HSI Control	S	70	-0	70	50 - 5 = 45
* Performance Chart Recall	S	70	-0	70	50 - 5 = 45
* Air Conditioning Control	S	70	-0	70	50 - 5 = 45
*Autopilot Interact/Setup	S	70	-0	70	50 - 5 = 45
? Checklist Recall	S/M	65	[illegible]	63	41 - 5 = 36
Master Recognition List	M	60	-5	55	32 - 5 = 27
? Emergency Recall Procedure	S/M	65	-2	63	41 - 5 = 36
? Fuel Management	S/M	65	-2	63	41 - 5 = 36
* Circuit Breaker Status	S	70	-2	68	50 - 5 = 45

NOTES: Calculations are based on basic feasibility ratings for generic isolated word recognizers (IWR) and connected word recognizers (CWR), assigned according to vocabulary confusability, for the example vocabularies. Noise effects were then introduced, reducing the feasibilities for moderate vocabulary IWR, and for all CWR vocabularies by an equal amount (5 points). Takeoff and landing have higher noise levels, and thus lead to further reduction in feasibilities during those mission segments.

* = Tasks may be considered highly feasible.
(*) = Tasks that are also quite feasible.
? = Indicates other reasonable feasible tasks.

Technological Feasibility vs Pilot Utility Ratings

An examination of the tradeoffs between utility and feasibility can be examined now that we have rated all tasks on these two dimensions. We have shown these tradeoffs in graphic form for the isolated word and connected speech models in Figures 15 and 16, respectively.

Examination of the Utility vs Technological Feasibility matrix reveals that there are several groupings within each scale. we have placed arbitrary divisions on the graphs to demarcate "high," "medium," and "low" utility and feasibility groups. The task names are listed in tabular form for these categories in Table 9.

Utility Groups

The high utility group is dominated by the two information retrieval tasks, Charts and Checklists/Emergency Procedures. Two pilot-suggested tasks, Fuel Management and Circuit Breaker Status, were included in this group, although not formally scored by questionnaires. Terrain avoidance procedures and tasks also appear in this group: Terrain Display Control and record Keeping in TA. These activities, as our time-based plots show, are occurring at high time-sharing demand for the crew.

The medium utility group consists of system control tasks which occur during high time-sharing demand, while the low utility group shows tasks without time-sharing or information retrieval components.

Technological Feasibility Groups

The high feasibility group consists of tasks that were judged to have "simple" recognition vocabularies and were not in the takeoff or recovery segments where noise would negatively affect recognition performance.

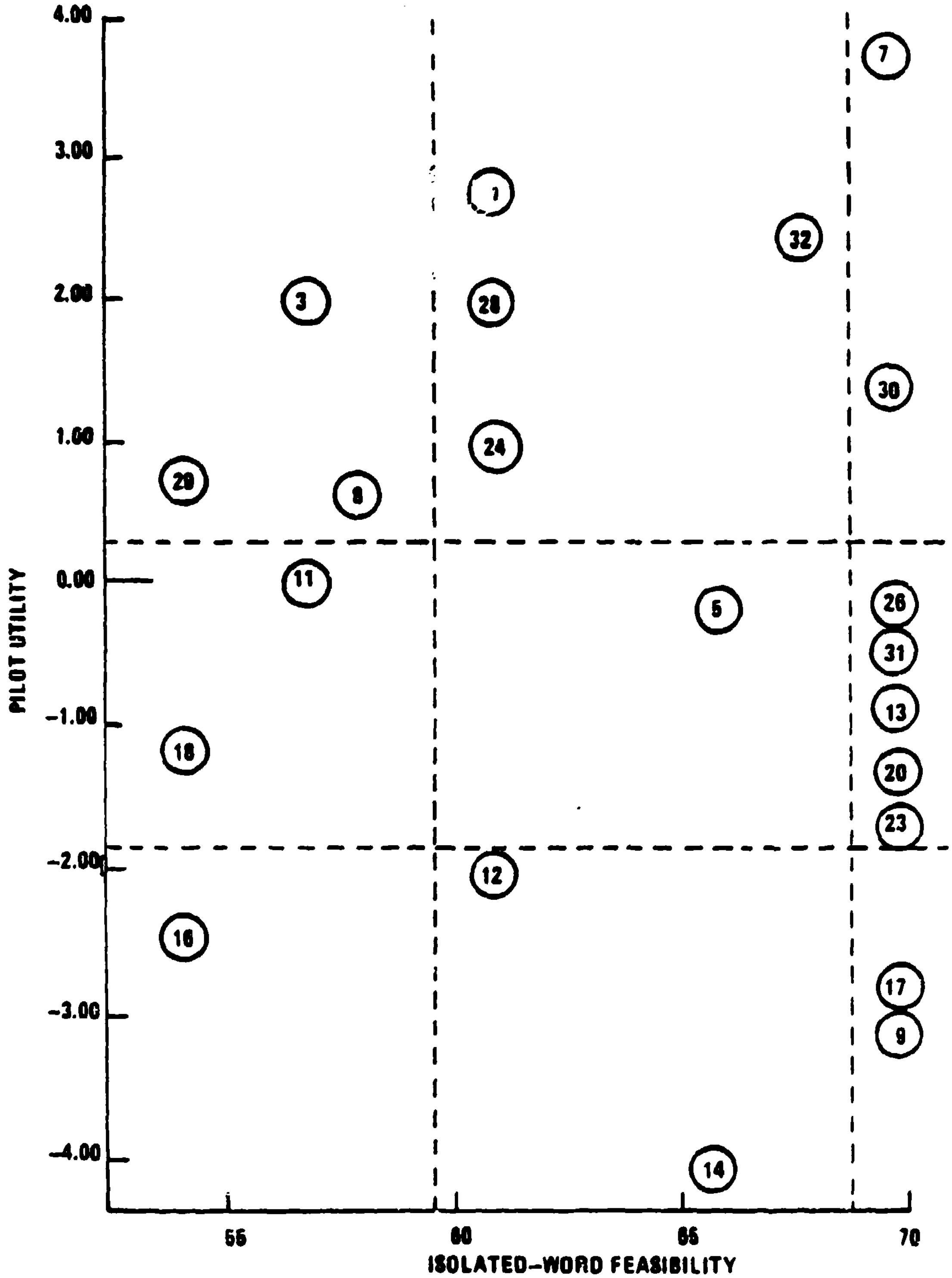

Figure 15. Utility vs Technological Feasibility for Isolated-Word Model

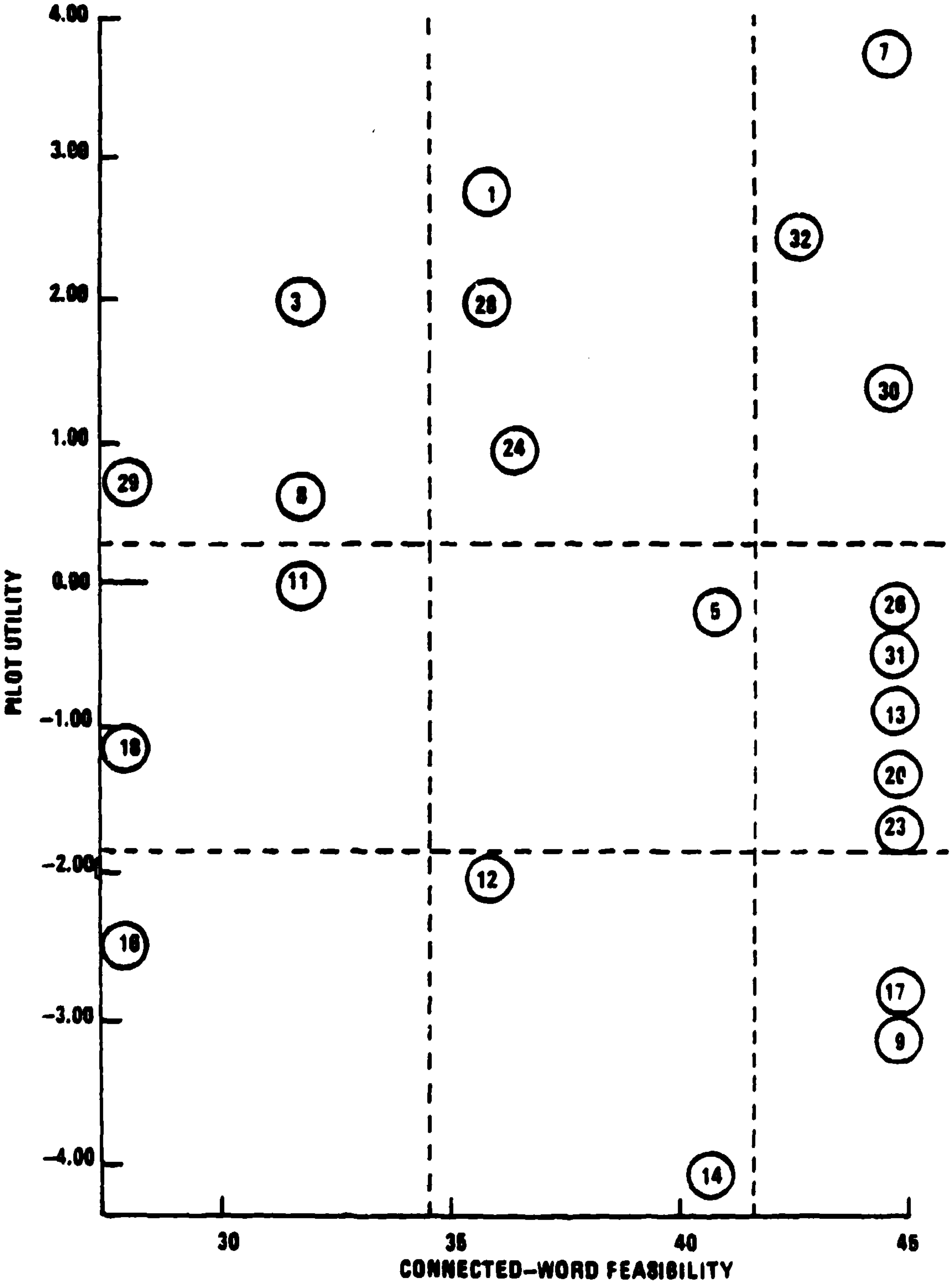

Figure 16. Utility vs Technological Feasibility for Connected-Word Model

TABLE 9. CATEGORIZATION OF UTILITY/FEASIBILITY SCALES FOR RECOGNITION TASKS

	Technological Feasibility		
Utility	Low	Medium	High
High	Record Keeping, TA Fuel Management	Checklist Retrieval Radio Frequency Control IFF Mode Control Clearance Plane Control Terrain Display Control	Chart Retrieval Circuit Breaker Status HSI Control
Medium		Navigation System Control Altimeter Setting	Radar Altimeter Setting Timer Start/Stop Autopilot Control EVS Control
Low	Refueling Panel	Fuel Panel Control Steering Ratio Selection	Bleed Selector Control Anti-Collision Lights Control Air Conditioning Control

The medium feasibility group includes tasks that were judged to have either "simple-to-medium" vocabularies, or had negative effects from noise.

The low feasibility group includes only tasks that had "medium" vocabularies, and were within mission segments with high noise problems.

Generation Task Utility

Only two tasks were superior in pilot utility ranks for generation tasks: Flaps Position Enunciation, and Circuit Breaker Status. Both require difficult visual tasks at present, and can occur during high time-sharing loads.

Medium utility was seen for Master Caution Panel Enunciation, Altitude Callouts, Airspeed Callouts, and To-Go Calls during bomb runs.

The low utility category included Slant Range Calls and Contact/Disconnect Calls during Refueling, and Bleed Selector Status during Low Level.

Generation Task Feasibility

A review of recent developments in speech generation has led us to the conclusion that the term "technological feasibility" does not readily apply to tasks that we have chosen for this technology. This is due primarily to the expanded capabilities of large scale integrated circuits and the memory capacity of these devices. The major limitation of this technology is the storage space to be used for the individual vocabularies because of the sample rate and storage of the analog waveform. With the higher memory capacity now available, it should be technologically feasible to provide the aircraft with high-quality, intelligible speech messages for all applications.

SECTION 4

RESEARCH STRATEGIES

Before AST can be successfully applied in the airborne environment, several major research issues must be resolved. In general, we can divide these into human factors and engineering issues, although these major headings are not mutually exclusive. As with any man-machine system, there are tradeoffs between these two factors that lead to the success rate of the application. This section will discuss various research issues and strategies for conducting this reasearch.

In Figure 17 we list the major human factors and engineering research topics in AST implementation. The dotted lines indicate linkage between the issue areas, i.e., areas that will require integration between the human factors and engineering communities. Each area is discussed individually.

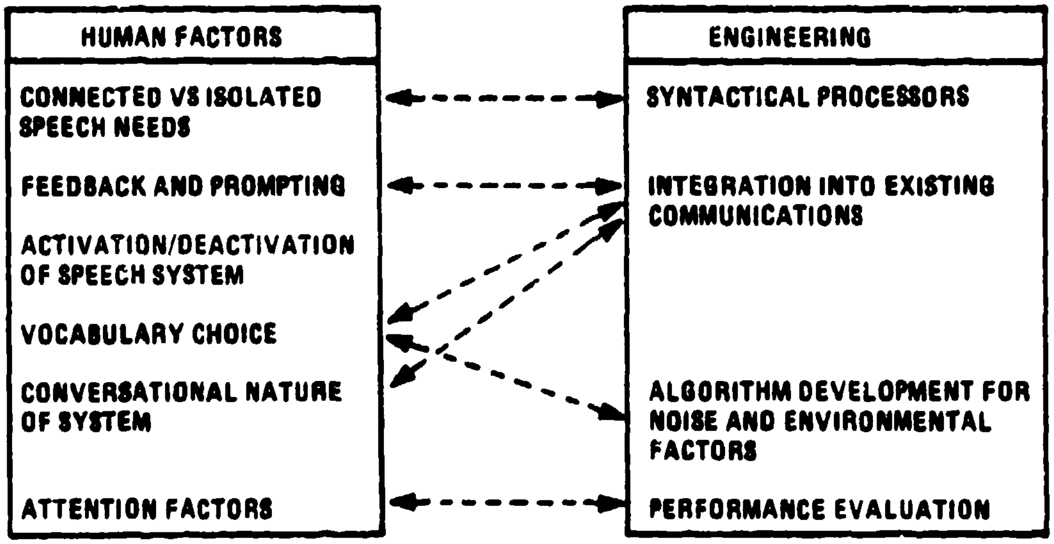

Figure 17. Research Issues in AST Implementation

HUMAN FACTORS RESEARCH ISSUES IN AST AIRBORNE APPLICATION

Recognition Issues

We have indicated several key recognition issues in the other sections of this report. Many of these issues have surfaced during the performance of this contract. Others are compiled from discussions with AST human factors personnel working in laboratories throughout the country and from issues arising in the performance of other ongoing speech/airborne application projects.

Need for Connected vs Isolated Speech--This topic is currently of interest because of the expanding capabilities of commercially available recognizers. It is important in the engineering sense because of the increased cost that connected or continuous speech devices will represent to the system.

If we can limit ourselves to the use of isolated word formats, we will save a substantial amount in device cost. The cost of this limitation to the pilot is unclear at present. There is a high need for research that defines the utility of progressing toward more "conversational" input represented by free-format, continuous speech. The performance of this contract has suggested that this need is not as great as we might have anticipated.

To be of maximum value to the pilot, continuous speech recognizers should be able to accept completely free-format, randomly constructed sentences. The initial attempts at continuous speech, however, show a high need for constrained formats (e.g., syntax structure rules) that require items to be said in specific orders. It is not clear what, if any, memory burden this will place on the human operator. Can the same task, if correctly prompted by visual or auditory means, be accomplished with an isolated word device?

How many tasks at a given crewstation could really benefit from continuous speech? Does learning influence the ability of the pilot to make these syntactically correct inputs required by a continuous speech system?

Research Strategy--We suggest that this research task can be readily addressed without sophisticated facilities (e.g., actual recognition hardware, simulators, etc.). Given a list of actual tasks that are of a "high utility" nature from the pilot's viewpoint, we could construct experiments that measure the time savings and the recall performance of the two techniques.

Feedback and Prompting Methods--Speech input requires the use of a method to "close the loop" for the operator so that inputs are verified as correct. Both isolated and continuous formats will need this capability. A second need for which large vocabularies are anticipated is adequate menus or prompts. This issue would impact the design of display formats, as it is anticipated that speech generation as a prompting technique will have decreasing utility as the size of the vocabulary increases.

The relevant questions surrounding these issues are:

- o How often should feedback be presented during an input transmission?
- o What form should the feedback take?
- o Can prompts be used as feedback in a multiple transaction?
- o What format should visual prompting take in menus?

Research Strategies--These issues should most likely be addressed with real-time simulation. Actual recognition hardware integrated into the simulation is desirable, but not absolutely required. Experiments should address one or two of these factors at a time, as large designs will lead to less power in the comparative tests. Experimental scenarios should be as

realistic as possible (e.g., intruding communications tasks, interruptions, etc.) to address the full range of problems that could occur in prompting/feedback implementation.

Activation/Deactivation of Speech Input System--This issue has surfaced in nearly every discussion with pilots and system designers. If the engineering behind the device is not capable of perfect rejection of speech not intended for the recognizer, then provision for on/off control must be made. Suggestions have included: 1) provision of an additional detent or "push to talk" switch when voice-in is needed; and 2) provision of a vocabulary item to "cue" the speech input system that inputs are starting (or ending). In general, the first method meets with the most approval by pilots, although this generalization is based on informal data. A systematic approach to resolving this issue is warranted.

Vocabulary Choice and Verification--The choice of proper vocabularies for each recognition task is closely tied to the present demarcations, labels, etc. on the system application. Since there are presently no linguistic rules for choosing utterances that are minimally confusable, it is logical to start with the conventional labels on the switches or controls. An issue concerns the "standardization" of vocabulary choice across pilots. Pilot consultation should be sought during vocabulary design to construct this standard vocabulary. When linguistic rules become available, they should be applied to change certain utterances in each vocabulary. Subsequently, these alterations should be filtered by pilots.

Engineering Issues

Noise, Vibration, Acceleration, and Other Environmental Effects--It has been documented that noise, vibration, acceleration, and other environmental factors will negatively influence recognition performance. Alterations in the waveform caused by these factors have not been well researched, however.

Some progress has been made recently in collecting data on speech input under degraded conditions. A serious need, however, is the design and conduct of rigorously controlled experiments. It is not known, for example, what may occur when these factors jointly influence performance. One experimental procedure that should be considered in strategies for research in this area is response surface methodology (RSM). RSM allows the collection of data over a wide range of values for each variable without a prohibitive number of data collection points in the design. RSM designs are discussed by Clark and Williges (1973) for human performance applications.

These tests should be performed with standard vocabularies chosen by the best possible method. The digits should be included as well as a standard set of vocabulary items. The aberrations caused by these variations in conditions should provide useful inputs to the recognition algorithm designer.

Integration into Existing Communication I/O System--Pilots have commented on potential conflicts with a speech input system during the mission. Any ground or interphone communication cannot be lost due to inputs from or to the speech system. The "prioritization" scheme must be rigorously examined between messaging from these various sources.

Syntactical Processing--The movement toward connected and continuous recognizers will require a syntactical processor. There are several systems emerging that approach this need (e.g., VRAS, HARPY, HEARSAY). Research is currently in progress to explore these approaches. Choice of processor will influence the sophistication of the recognition device firmware. Each airborne application should be examined for the need of syntactical structure to determine the extent of sophistication in the processor (e.g., number of nodes per transaction, number of ways transaction can occur, etc.). For example, syntax may be required for discrete word devices to aid performance in the hostile environment of high-performance aircraft.

Generation Issues

As was mentioned in the technological feasibility section, the majority of problems with speech generation application in the cockpit are human factors issues. Engineering issues have become less troublesome with the expansion of memory capacity. the human factors issues are largely unresolved, however. These issues, and strategies for exploring them, are discussed below.

Attention Factors--An effective voice warning system will quickly draw the attention of the crewmember to the problem, but certain qualities in the speech signal may be more alerting than others. It is not known what effect rate, intonation pitch, localization, etc. will have on gaining the pilot's attention. Repeating the message, or cueing prior to the enunciation of the message, may also be of benefit. Laboratory and simulator testing should be undertaken to resolve these issues. We recommend that a flexible speech generation device of the "digital tape recorder" type be used in these determinations. This type of device has advantages over the predesigned wordset device because it gives the researcher the ability to create a message of any type, inflection, speed, etc., and randomly access each message during the simulation.

Conversational Cockpits--Pilots have expressed the desire to avoid having conversations with onboard devices. This is currently based on opinion without any first-hand experience with such a system. Nevertheless, it may be necessary to learn how much conversation is needed in the course of completing a task that uses a speech recognition device. Style and length of prompting messages during a given transaction are of interest. These issues can also be addressed in simulation experiments.

Performance Evaluation--Performance evaluation is another high-priority area for further work in automatic speech generation. To ensure informed selections, immediate attention should be directed to the side-by-side comparison of available devices for speech generation. It is also crucial to develop and use quantitative measures of intelligibility and voice quality to guide the assessment of speech generators. Of moderate importance are issues of how to measure the total difficulty of speech generation tasks, and how to detect sources of inadequacies in synthesizers by evaluating various components in the systems.

Additional Issues--Other issues concerning research strategies for speech recognition/generation will be summarized in a subsequent separate document. This document, by Wayne A. Lea, will be entitled "Research Strategies in Airborne Application of Speech Technology."

SECTION 5

USER BRIEFING GUIDELINES

During this program, we have learned much about effective methods of briefing users about speech technology and how these methods may affect the aircraft they fly in the future. A format for introducing these concepts is important for gaining the pilot community's understanding of AST. Presentations and demonstrations should be as relevant and efficient as possible to provide an understanding of the current and future state-of-the-art of AST, and allow the user to begin applying his knowledge of the aircraft to aid AST implementation.

BRIEFING FORMAT TOPICS

Usually, the operational mode does not afford the presentor adequate time to educate his audience about the engineering details of AST. A limited explanation is best, with more attention to relevant examples and "hands on" demonstrations with the audience. A typical sixty-to-ninety minute briefing could include these agenda items:

- Example demonstrating the importance of AST to the mission.
- Introduction to AST technologies and a review of SOA.
- Presentation of demonstration examples from the mission.
- "Hands-on" participation sessions.
- Research issues.
- Questions and discussion.

Each of these topics is treated in more detail below.

Example Demonstrating the Importance of AST in the Mission

The concept of command by voice or listening to a synthetic (non-human) device is foreign to many pilots. Voice warnings, however, are more prevalent and so more widely known. A simple example aids the "attention-getting" quality of the briefing. The example should be tied to an operating procedure on the relevant aircraft.

Introduction to AST

There should be a brief discussion of the technical aspects of the two speech technologies, but without any in-depth detail on the engineering of hardware devices. The block diagram approach is a helpful means of explaining the rudiments of speech systems. For recognition, the major types of available systems should be discussed along the dichotomies of speaker dependent vs independent, and isolated vs connected word recognition. For speaker-dependent systems, the training procedure should be explained, including current/future methods of storing recognition templates (e.g., bubble memory, digital recording devices, EPROMS, etc.). Recent data collection on the effects of vibration, noise, and acceleration should be highlighted in light of their impact on future system accuracy.

Distinctions between continuous or connected speech and isolated word formats can be explained by examples from the operation of an onboard system (radio frequency examples, with the isolated word vs connected word formats in some tasks). More complex tasks requiring "programming" formats such as "warn when fuel below three thousand pounds" are good continuous speech examples. Simple tasks such as checklist retrieval ("landing checklist") are good isolated word task examples.

The current directions in recognition systems toward continuous or connected word systems should be highlighted, emphasizing the current success of isolated-word, speaker-dependent systems.

The two major methods of speech generation should be included in this introduction period. Synthesis vs digitized speech should be defined, and examples of current speech output devices could be used to demonstrate the quality differences. The rapid development in this technology and its relative ease of implementation compared to speech generation should be emphasized.

Demonstration of Systems

A portable speech recognition/generation system using a micro-computer and a stand-alone speech I/O system can be used as a demonstration tool. Preprogrammed mission examples are desirable, with several major mode selections branching to two or three hierarchical levels. If time does not permit this development, a relevant vocabulary can be chosen to represent a task. Prompting displays using a CRT or the voice generation system should be obvious and emphasized in the demonstration. An interactive dialogue format using both input and output is very helpful in grasping the operational nature of an AST system.

Examples should be generally simple, short, and allow users to see quickly the capabilities of the system. For recognition, error types should be demonstrated and their impact discussed. Both misrecognition and rejections should be shown.

"Hands-On" Participation Sessions

Training the system during the briefing can be helpful in understanding this procedure. Small vocabularies should be used. Audience participation should be invited during this portion of the demonstration, but the presentor should maintain control of the input mechanism, because first-time users tend to exhibit little or no microphone discipline.

Research Issues

Current issues in applying AST to the airborne environment should be discussed briefly. For recognition, emphasis should be placed on the human factors problems associated with mission analysis, vocabulary choice, implementation scheme, and feedback/prompting. For voice generation, the issues of speaker sex, intelligibility, frequency of messaging and prioritization of messaging should be discussed.

Questions and Discussion

Time should be allotted for questions and discussions of the above topics. Opinions and ideas should be solicited from the pilot audience to expand the choice of applications and to help prioritize among current operational needs for AST systems.

SECTION 6

CONCLUSIONS

Performing this project has produced several valuable results in developing criteria and procedures for choosing airborne applications of AST:

- Conventional Task Analysis Procedures can be successfully used to create a framework for choosing AST candidates within a given crewstation and mission.
- Objective criteria (e.g., time-sharing, anthropometry) for choosing candidates for AST, and subjective data (pilot opinion) agreed favorably, lending validity to the objective procedures used.
- Pilots can lend a significant input to the AST application choices when properly briefed on the capabilities and limitations of speech devices.
- The communication structure of the aircraft must be carefully examined; speech input and output should not "clutter" the verbal and auditory channels. Transactions should be short.
- The technological feasibility of task candidates varies with noise and vocabulary constraints of each task, but several high feasibility/high utility tasks were identified.
- Information Retrieval and "Programming" tasks are looked upon as "high utility" candidates for speech technology. Conventional discrete control tasks, if performed in time-sharing conditions, were also high utility items.

The primary objective of this program, to develop a methodology for identifying the highest priority tasks for speech I/O in a given crewstation and mission, was achieved. The verification and validation of the procedure outlined here should be undertaken through laboratory testing, simulation research, and finally, flight testing. Empirical evidence should be gathered whenever possible to support conclusions. It is the responsibility of the human factors engineer and system designer to coordinate efforts with the pilot community in these validation efforts and ensure the most cost-effective applications of speech technology.

SECTION 7

REFERENCES

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APPENDIX A - TASK NARRATIVES

Mission Segment: Takeoff

Time Frame: 0140

Page: 1

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Climbs into pilot seat.	Climbs into copilot seat.	
Responds to pilot interior inspection checklist.	Responds to copilot interior inspection checklist.	
	11. Set circuit breakers.	
12. Set circuit breakers.	12. Set battery switch off.	
13. Set autopilot servos cutout switches in.	13. Set battery charge switch off.	
14. Set IFF master switch to standby and set codes.	14. Open manifold valve.	
15. Set antiskid switch on and close guard.	15. Set all engine starter switches to off and pneumatic.	
16. Set Mach indicator switch on.	16. Set generator selector switch to central bus tie.	
17. Check AGM-69A consent panel guards closed and sealed.	17. Check generator drive decoupler switches in normal.	
18. Check AGM-69A launcher hydraulic control switch off.	18. Check air outlet knob is ½ out.	
19. Set hydraulic standby pump switches off.	19. Check and set clock.	
20. Set rudder/elevator hydraulic switches off.	20. Check all fuel system switches off and closed.	

TASK NARRATIVES

Mission Segment: Takeoff | **Page:** 2

Time Frame: 0140 | **Date:** 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
21. Set pilot's flare set power switch off.	21. Check landing gear lever is down and in detent.	
22. Check air outlet knob is ½ out.	22. Set air conditioning panel.	
23. Check and set clock.	23. Check and stow thrust gate.	
24. Set anti-icing switches off.	24. Check throttles closed.	
25. Check emergency landing gear switch guards closed.	25. Check drag chute lever and check locked.	
26. Disengage yaw and pitch SAS switches	26. Set wing flap lever down.	
27. Check steering ratio selector lever in takeoff-land.	27. Check terrain display mode selector switch off.	
28. Check airbrake lever off.	28. Close air conditioning head outlet.	
29. Check stabilize trim cutout switch guard closed.		
30. Check lateral trim cutout switch guard closed.		
31. Set crosswind crab knob and indicator down and zero.		
32. Close air conditioning head outlet.		
Informs copilot that interior inspection checklist complete.	Informs pilot that copilot interior inspection complete.	

TASK NARRATIVES

Mission Segment: Takeoff

Page: 3

Time Frame: 0145

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Reads Before Starting Engines Checklist and responds to checklist.	Responds to checklist.	
1. Checks oxygen system.	1. Checks oxygen system.	
2. Checks interphone operation.	2. Checks interphone operation.	
3. Set gyro power switch on.	3. Set gyro power switch on.	
4. Check emergency D-C power.	4. Check emergency D-C power.	
	5. Turn battery switch on.	
	6. Check generator switches.	
	7. Set external power switch on.	
8. Press to test all warning and indicator lights.	8. Press to test all warning and indicator lights.	
9. Check EVS power switch off.	9. Check EVS power switch off.	
10. Check oxygen quantity.		
11. Set engine fire shutoff switches to normal and check fire detector systems.	11. Set engine fire shutoff switches to normal and check fire detector system.	
12. Set AJN-8 Hdq. mode select switch to magnetic.		
13. Set navigation lights to bright and flash.		

Mission Segment: Takeoff | Page: 4

Time Frame: 0145 | Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
14. Request ground to connect and clear bomb doors.		GC - Advises bomb doors connected and clear.
	15. Set radios on.	
17. Perform fuel quantity check.	17. Perform fuel quantity check.	
18. Check radios (VOR, TACAN).	18. Check radios (VHF, LOS, Liaison). Command post check-in. Copies ground control on VHF 1 for altimeter setting. Ground control check-in on VHF 2.	
19. Check and reset altimeters.	19. Check and set altimeters in standby.	
20. Check and set AIMS (IFF).		
21. Check elevators and rudders.	21. Check elevators and rudders.	GC - Reports position of rudders and elevators to crew.
22. Request ground to remove ground locks and bypass keys.		GC - Advises ground locks and bypass keys removed.
23. Check standby hydraulic pump pressure.		
24. Check and turn off autopilot.		

TASK NARRATIVES

Mission Segment: Takeoff

Page: 5

Time Frame: 0145

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
25. Check airbrake, spoiler and lateral trim.	25. Check airbrake, spoiler, and lateral trim.	GC - Reports position of spoilers and airbrakes to crew.
26. Set wing system standby pump switches off.		
	27. Check wing flaps operation.	GC - Reports flap position and movement to crew.
28. Check fuel panel switches.	28. Set fuel panel switches.	
29. Check gyro instruments.	29. Check gyro instruments.	
30. Check J-4 Hdq (H).	30. Check J-4 Hdq (H).	N-30. Advises J-4 Hdq (H) checked.
		N-31. Advised ground locks and bypass keys counted and stowed.
32. Reports crew report completed.	32. Report copilot check complete.	N, G, EW, RN-32. Report crewmembers check complete.
		GC - Advises pilot of alarm system status.
33. Set steering ratio selector lever to taxi.		
34. Set windshield anti-icing and defog switch to normal.		

TASK NARRATIVES

Mission Segment: Takeoff — Page: 6

Time Frame: 0145 — Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
35. Check circuit breakers. Advises crew that Before Starting Engines Checklist is completed.	35. Check circuit breakers.	

TASK NARRATIVES

Mission Segment: Takeoff | Page: 7

Time Frame: 0240 | Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
	Request clearance to start engines from ground control.	
Reads Starting Engines and Before Taxiing Checklist.	Responds to checklist.	
1. Set parking brakes.		
	2. Set battery switch on.	
3. Check interphone power switch on.		
	4. Set external power on.	
5. Request ground to close hatches.		GC - Acknowledges request and closes hatches.
6. Request ground to start external air.		GC - Acknowledge request and starts the external air.
7. Advise crew to stand by to start engines.		GC - Advises pilot fire guard posted and clear.
8. Request CP to start engines.	8. Starts engines. Monitors engine instruments. Advance throttles to idle.	
		GC - Advises external air disconnected.

Mission Segment: Takeoff

Time Frame: 0240

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
	9. Checks starter caution light out.	
10. Sets engine anti-icing switch.		
	11. Close manifold valve switch.	
	12. Set generators on. Verify battery lights out.	
	13. Checks liaison radio on.	
14. Request ground to clear aircraft for taxi.		GC - Acknowledges request and disconnects and removes all ground support equipment.
15. Set body system standby pump switches off.		
16. Sets rudder/elevator hydraulic switches on and verifies lights out.		
17. Checks hydraulic system pressures.		
18. Check AGM-69A launcher hydraulic control switch off.		
	19. Set air conditioning master switch to 7.45 psi and notify RN&G cooling air is available.	

TASK NARRATIVES

Mission Segment: Takeoff — Page: 9

Time Frame: 0240 — Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
20. Check stabilizer trim. Set takeoff trim.	20. Check stabilizer trim.	GC - Reports position of leading edge.
21. Set and adjust EVS.	21. Set and adjust EVS.	
22. Set EVS manual steering.		
23. Cr[illegible] equipment donned and adjusted.	23. Crew equipment donned and adjusted.	
25. Request ground to remove wheel chocks and disconnect interphone.		GC - Acknowledges request and removes wheel chocks and disconnects interphone.
	26. Sets anticollision and navigation lights on and steady.	
27. Announces to crew to stand by to taxi.		

TASK NARRATIVES

Mission Segment: Takeoff | **Page:** 10

Time Frame: 0245 | **Date:** 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
	Request launch message from Command Post. Copies launch message.	
	Copies taxi instructions from ground control.	
Receive clear to taxi visual signal from ground crew.		
Releases brakes.		
Steers a/c with rudder pedals to end of runway.		
Maintain speed with brakes.		
Calls for Taxiing checklist.		
	Reads and responds to check list while clearning for obstructions.	
Responds to checklist.		
1. Check brakes. Monitor master and central caution lights.		
	2. Lower flaps.	
3. Close bomb doors.		
4. Set radio altimeter cursor to 500 feet.	4. Set radar altimeter cursor to 500 feet.	

TASK NARRATIVES

Mission Segment: Takeoff | **Page:** 11

Time Frame: 0245 | **Date:** 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
5. Check flight instruments.	5. Check flight instruments.	
	6. Checks generator panel.	
7. Check crosswind crab system.	7. Check crosswind crab system.	
	Informs crew Taxiing checklist completed.	
Parks aircraft in holding area at the end of the runway.	Clears for obstructions.	
Calls for Before Takeoff Checklist.	Reads and responds to checklist.	
Responds to checklist.		
1. Set parking brakes.		
2. Set pitot heat on.		
3. Engage yaw and pitch SAS switches. Verify channel fail light out.		
4. Set control surface trim for take-off setting.	4. Set control surface trim for take-off setting.	
5. Check stabilizer trim for takeoff setting.	5. Check stabalizer trim for takeoff setting.	

TASK NARRATIVES

Mission Segment: Takeoff | **Page:** 12

Time Frame: 0245 | **Date:** 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
6. Set airbrake lever off.		
7. Check wing flap position and lever down.	7. Check wing flap position and lever down.	
8. Recheck fuel panel switches.	8. Check fuel panel switches.	
9. Check windows and hatches closed and locked.	9. Check windows and hatches closed and locked.	
10. Recheck and set flight instruments.	10. Recheck and set flight instruments.	N-10. Recheck and set flight instruments.
11. Set and check radio navigation instruments for departure (VOR/TACAN).	11. Set and check radio navigation instruments for departure (VOR/TACAN).	
12. Check air conditioning head outlets closed.	12. Check air conditioning head outlets closed.	
	13. Set starter selector switch to flight.	
14. Review takeoff data.	14. Review takeoff data.	N-14. Review takeoff data.
	15. Set thrust gate for takeoff.	
16. Seat, rudder pedals, and control column adjusted and checked.	16. Seat, rudder pedals, and control column adjusted and checked.	

TASK NARRATIVES

Mission Segment: Takeoff

Page: 13

Time Frame: 0245

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
17. Remove arming lever safety pins (No. 1).	17. Remove arming lever safety pins (No. 1).	EW, G-17. Remove arming lever safety pins.
18. Set IFF mode and code as briefed.		
	19. Set taxi lights on.	
	Completes Before-Line Up Checklist and informs pilot checklist complete.	

TASK NARRATIVES

Mission Segment: Takeoff — Page: 14

Time Frame: 0300 — Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Copies ATC and departure clearance. Responds to guard check with ground control.	Copies call from ground control with clearance. Copies ATC and departure clearance.	
Copy ground for final weather check. Confirms active and alternate runway.	Copies weather. Verfies all heading systems reference magnetic north.	
Copies takeoff briefing, including ATC clearance, radar departure, emergencies on departure and emergency IMC return.	Copies briefing. Verifies command nav set up for departure and emergency IMC return.	
	Calls in "ready for takeoff".	
Reviews takeoff procedure and the SID.	Switches to tower frequency as requested. Reviews and verifies takeoff data.	
Reviews Takeoff checklist.	Reviews Takeoff checklist.	
	Request permission to takeoff from tower.	
	Receives clearance from tower for takeoff. Switches to departure control frequency as requested.	

Mission Segment: Takeoff

Time Frame: 0315

Page: 15

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Releases brakes. Advances power for takeoff. Maintains directional control and assumes yoke control. Maintains visual runway alignment. Checks crosswind crab. Set engine stall prevention switch to climatic.	Sets crosswind crab. Set air conditioning master switch to RAM. Set steering ratio selector lever to takeoff-land. Adjusts throttles to attain proper takeoff EPR.	
Monitors airspeed.	Monitors engine instruments (oil pressure, EPR, rpm, and EGT indicators) and airspeed.	
	Monitors stablizer trim indicator.	
Calls "70 knots, NOW."	Crosschecks airspeed.	
Checks airspeed.		N - Calls "coming up on _____ seconds, NOW."
Calls "committed."	Takes control of throttles and sets throttle brake.	
	Calls "coming up on unstick speed, NOW."	
Pulls back on yoke and lifts off. Applies wheel brakes. Calls "flaps up" at flap retract altitude and accelerates to enroute climb speed. Monitors flight instruments.	Monitors airspeed and altitude. Retracts flaps on pilot command. Monitors aircraft systems.	

TASK NARRATIVES

Mission Segment: Takeoff

Time Frame: 0315

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Cross Hickman INT at 4000 feet. Turns toward departure route (Hickman LIN R-149). Selects flight director for heading. Monitors flight instrument guidance. Set thrust gate.	Responds to towers comm frequency change. Sets flight director to capture departure route. Accelerates to 280 KIAS enroute climb.	

TASK NARRATIVES

Mission Segment: Takeoff

Time Frame: 0318

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Responds to departure control heading and altitude direction. Maintains flight instrument reference. Calls for After Takeoff-Climb checklist.	Responds to calls from departure control. Reads and responds to checklist.	
	1. Set air conditioning master switch to 7.45 psi.	
	2. Open, then close slipway doors.	
Flies departure vector enroute to Santa Rite Int, maintaining flight instrument reference.	Responds to IFF squawk from departure control. Receives clearance to climb to cruise altitude, to cross Santa Rita Int at or below FL 200. Requests direct routing to Friant VOR.	
	Turn autopilot on for warmup. Disconnect zero delay lanyards.	
	3. Complete 12,000 ft. oxygen check.	G, RN-3. Complete 12,000 feet oxygen check.
Turns aircraft left to 080°. Selects flight director for nav guidance.	Acknowledges departure control's directive to turn left to 080° and squawk identification. Maintains outside scan.	
4. Checks fuel panel.	4. Sets up fuel panel.	

Mission Segment: Takeoff

Time Frame: 0318

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Engages autopilot to capture desired heading. Monitors flight instruments, comm radio and outside watch. 5. Resets altimeters to 29.92.	Responds to departure control VHF frequency change directive to contact Oakland Center. 5. Resets altimeters to 29.92. Responds to IFF change from Oakland and acknowledges request for present altitude. Responds to VHF frequency change to Oakland Center.	

TASK NARRATIVES

Mission Segment: Takeoff

Time Frame: 0333

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Accomplishes level off at FL 280. Monitors flight instruments and outside watch.	Reports level at 280 Radio comm switched from control tower to Command Post.	
6. Complete level-off check.	6. Complete level-off check.	
a. Turn landing, taxi and cross-wind landing light switches off.	a. Turn landing, taxi and cross-wind landing light switches off.	
b. Oxygen check.	b. Complete oxygen check.	G, RN-b. Oxygen panels checked.
c. Station checks.	c. Station checks.	
- Circuit breakers	- Circuit breakers	
- Fuel panel	- Generators	
- Oxygen quantity	- Fuel panel	
- Hydraulic systems	- Engine instruments	
- Anti-icing systems		
d. Set thrust gate to 85°.	d. Set thrust gate to 85°.	
e. Set starter switches to climatic.	e. Set starter switches to climatic.	

MISSION SEGMENT:

AIR REFUELING

TASK NARRATIVES

TASK NARRATIVES

Mission Segment: Air Refueling — **Page:** 1

Time Frame: 0430 — **Date:** 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Monitors flight instruments. Scans outside the aircraft. Gradually climbing to rendezvous altitude of 29,000 ft.	Copies message from tanker informing of total fuel offload available.	RN - Calls slant range to tanker in 10 NM increments. Calls range at 60, 50, and 40 NM.

TASK NARRATIVES

Mission Segment: *Air Refueling* — Page: 2

Time Frame: 0433 — Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Levels off at rendezvous altitude. Monitors flight instruments. Informs tanker of level flight at 29,000. Copies tanker range calls. Copy tanker level flight at 30,000.	Monitors altitude. Calls "level off altitude at 29,000. Copies tanker range calls. Scan outside aircraft.	RN - Calls slant range to tanker in 1 NM increments. Calls at 25 . . . 22 NM.

TASK NARRATIVES

Mission Segment: Air Refueling | **Page:** 3

Time Frame: 0434 | **Date:** 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Calls for tanker to begin turn. Monitors flight instruments. Copies tanker half-way through turn. Calls tanker with visual identification.	Scan outside aircraft. Visually detects tanker lights and informs crew. Cross-checks range.	RN - Calls slant range to tanker in 1 NM increments. Calls range at 21 . . . 4 NM.

TASK NARRATIVES

Mission Segment: Air Refueling

Page: 4

Time Frame: 0436

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Calls for Preparation for Contact checklist.	Reads Preparation for Contact checklist.	RN - Calls range to tanker in 1 NM increments. Calls range at 3 . . . . 2 NM.
1. Establish radio contact.		
	2. Check air conditioning system.	
		N - 3. Set rendezvous radar to standby
	4. Turn anticollision lights off.	
	5. Turn navigation lights to flash.	
6. Disengage autopilot.		
7. Set airbrake lever to position 1.		
	6. Set slipway and airplane light switches to full bright.	
	7. Open slipway doors and verify ready lights on.	
	8. Determine tanker position on FLIR sensor.	RN - 8. Determine tanker position on FLIR sensor.
9. Select FLIR video.		
	10. Set air refueling switch to air refuel.	

TASK NARRATIVES

Mission Segment: Air Refueling

Time Frame: 0436 (continued)

Page: 5

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
	11. Reset signal amp.	
		G - 12. Position FCS switches as required.
	13. Set TACAN.	
	Informs crew Preparation for Contact checklist complete.	

TASK NARRATIVES

Mission Segment: Air Refueling

Time Frame: 0438

Page: 6

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Calls tanker at 1 mile, informs tanker speed is 270 and beginning climb to 500 ft. below and 1/2 mile behind tanker. Initiates slow climb to 500 ft. At 1/2 mile range, speed reduced to 260. Turn autopilot to aerial refuel mode.	Visually track tanker.	N - Calls range at 1 and 1/2 NM.

TASK NARRATIVES

Mission Segment: Air Refueling

Time Frame: 0440

Page: 7

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Copies boom operators radio check and refueling order. Stablize aircraft in precontact position and infroms tanker (50 ft. aft - 10 ft. below. Copies boom operator's orders clearing buff to contact position. Copies boom operator's directions and monitors director lights. Decreases power slightly. Retrim stablizer to fly formation on the tanker. Lowers position for better view of tanker. Moves aircraft forward and up until boom is in the slipway and nozzle is secured in place.	Copies boom operator's radio check and refueling order. Dims cockpit lighting as required. Maintains visual contact with tanker. Checks engine instruments.	

TASK NARRATIVES

Mission Segment: Air Refueling — Page: 8

Time Frame: 0442 — Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Copies contact from boom. Informs tanker of contact.	Copies contact from boom. Verifies contact on air refueling lights.	
Copies boom that buff is receiving fuel.		
Flies tanker observing director lights--one hand on control column and one on throttle and eyes on tanker. Slowly increase power as fuel is on-loaded.	Informs pilot of tanks being filled. Monitors fuel management panel to maintain required center of gravity (CG). Checks flight instruments.	

TASK NARRATIVES

Mission Segment: Air Refueling

Page: 9

Time Frame: 0447

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Flies formation on tanker.	Monitors fuel management panel. Informs pilot CG is moving forward. Checks panel and determines aft body tank is not filling. Checks switch placement OK. Informs pilot main manifold valves stuck. Closes valves 25 and 26 to forward body and center wing tanks. Determines fuel load required to complete mission.	
Informs tanker of fuel management problem and of partial load to be accepted.		

TASK NARRATIVES

Mission Segment: Air Refueling — Page: 10

Time Frame: 0457 — Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Flies in formation on tanker.	Refuel mid-body to full, mains 1 and 4 to upper limit of green band, and mains 2 and 3 to 17,000 lbs. each. Close valve 27, 19-22. *Inform pilot* refueling complete.	
Copies boom that fuel has been received.	Copies boom that fuel has been received.	
Informs tanker of practice connects and disconnects. Inform tanker to disconnect on count of three "1,2,3."		
Copy boom's disconnect signal. Inform tanker of disconnect.	Monitor air refueling indicator lights. Reset signal amp.	
Slightly descreases power to achieve separation		
Stabilize aircraft in precontact position.		
Practice connects and disconnects as above.		

TASK NARRATIVES

Mission Segment: Air Refueling — **Page:** 11

Time Frame: 0520 — **Date:** 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Inform tanker final connect to be made, tanks to be topped off, stabilized in precontact position. Note altimeter reading. Copies boom's directions and monitors director lights. Decrease power slightly. Move aircraft to contact position. Copies contact from boom. Informs tanker of contact.	Copies contact from boom. Verifies contact on air refueling indicator lights.	
Flies formation on tanker.	Open switches 19-22 and 27 on fuel management panel. Informs pilot of tanks being filled. Close valves when full. Copy boom's message of tanks filled.	
Copy boom's message of tanks filled. Inform tanker ready to practice break-away.		

TASK NARRATIVES

Mission Segment: Air Refueling　　　　**Page:** 12

Time Frame: 0532　　　　**Date:** 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Copy tanker's command to practice breakaway. Calls "breakaway, breakaway, breakaway." Depress and hold autopilot disconnect and air refueling boom release button. Retard throttles to idle. Establish and observe positive rate of descent. Drop aft until entire tanker is in sight. Monitor flight instruments. Call clear tanker.	Depress and hold a/p disconnect and air refueling boom release button. Maintain visual contact with tanker until clear.	

MISSION SEGMENT:

LOW-LEVEL BOMBING RUN

TASK NARRATIVES

TASK NARRATIVES

Mission Segment: Low-Level Bomb Run

Page: 1

Time Frame:

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Calls for low-level descent checklist.	Reads and responds to low-level	N-calls out navigation instructions to pilot.
Responds to checklist	Descent checklist	
Flies aircraft on autopilot. Monitors flight instruments	1. Calls PFSV station and obtains updated altimeter settings and "D" values.	
	2. Check bleed selector switch in normal LH INBD.	
3. Turn on EVS and select TA video.	3. Turn on EVS and select TA video	
	4. Check starter switches	
5. Set anti-icing panel as required.		
	6. Set stabilization reference selector switch to FVR.	
7. Set clearance plane to 800 Ft.	7. Set clearance plane to 800 Ft.	
8. Set radar altimeter cursor to 800 Ft.	8. Set radar altimeter cursor to 800 Ft.	
	9. Turn taxi lights on.	N-Calls out descent point location to low-level.
10. Set altimeters	10. Set altimeters	N-10 Set altimeters
11. Disengage autopilot		
Flies aircraft-monitors flight instruments		N-calls descent point

TASK NARRATIVES

Mission Segment: Low-Level Bomb Run

Page: 2

Time Frame:

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Retards throttles to idle, begins descent from FL 200 to 17,000 ft. at 280 KIAS. Monitors flight instruments.	Calls Oakland to cancel IFR. Continuous with low level descent checklist.	N-Calls altitude during descent.
	13. Set terrain display mode selector switch to Profile 10.	
	Monitors engine instruments, full panel, caution panels.	
14. Accomplish level off at IFR altitude emergency safe altitude.	14. Verify altitude.	N,RN - Verify altitude
15. Set autopilot switch to low level		
16. Check radar altimeter and pressure altimeter	16. Cross-check altimeters	N-Calls terrain elevation N,Rn-16 Cross check altimeters
17. Set altimeters	17. Set altimeters	17 - Set altimeters
		RN-calls range to TA calibration area
		RN-clears us to descend to TA calibration altitude
Begins descent to 9000 feet	Monitors outside the aircraft	

TASK NARRATIVES

Mission Segment: Low-Level Bomb Run — Page: 3

Time Frame: — Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Levels off at 9,000 ft., 220 KIAS, gear & flaps up, airbrakes down	Continually monitors outside the aircraft and on EVS for safe terrain clearance	
		RN-Calls approach to TA calibration area
Calls for TA system calibration checklist	Reads items 1-3 of TA system checklist	
1. Levels off at TA calibration altitude	1. Verifies altitude	RN,N-1. Verify altitude
2. Sets autopilot in altitude hold		
3. Checks radar & pressure altimeters	3. Cross-checks altimeters	RN,N-3. Cross-checks altimeters
Request CP take control of aircraft	Takes control of aircraft	
Reads TA system calibration checklist		
4. Compares stabilization modes		
5. Sets stabilization reference selectors switch to FRL		RN-calls for trace range settings
6. Perform peak checks - check tilt errors	6. Checks tilt errors	RN-6, Checks tilt errors
	Flies aircraft over point being tracked	N-Calls directions to point being tracked

TASK NARRATIVES

Mission Segment: Low-Level Bomb Run | **Page:** 4

Time Frame: | **Date:** 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Determines zero range absolute altitude	Determines zero range absolute altitude	
6. Performs flat terrain checks		
		N-6a. Compute and set FRL calibration value.
b. Set terrain display mode selector switch to PROFILE 3		
c. Reads clearance plane value and radar altimeter altitude		N-6c. Computes bias compensation value.
d. Set clearance plane calibration value		N-6d. Computes clearance plane calibration value
e. Determine tilt compensation value		N-6e. Determine tilt compensation value
	7. Set autopilot low level switch to low level	
8. Resets altimeters	8. Calls FCC for current altimeter setting. Resets altimeters	N-8 Resets altimeters
10. Compare FRL & FVR stabilization modes		RN-10 Compare FRL & FVR stabilization modes.

TASK NARRATIVES

Mission Segment: Low-Level Bomb Run

Page: 5

Time Frame:

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
11. Set stabilization reference selector switch to FVR/FRL.		
12. Sets clearance plane to briefed TA altitude	12. Checks clearance plane set to TA altitude	
13. Set radar altimeter cursor to briefed TA altitude	13. Set radar altimeter cursor to briefed TA altitude.	
Informs copilot taking control of aircraft.	Acknowledges requests for aircraft control.	
14. Makes final descent to TA altitude		
During TA avoidance, pilot monitors TA display, radar altimeters and flight instruments.	During TA avoidance, co-pilot will visually monitor the terrain clearance of the aircraft and aircraft systems operation.	N-Calls out course, range, checkpoints and visual landmarks. RN-Calls out high terrain ahead - suggests course changes around high terrain

TASK NARRATIVES

Mission Segment: Low-Level Bomb Run

Page: 6

Time Frame:

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Continues to fly low-level altitude 1300 ft. Enter bomb run corridor -- accelerate to 330 KIAS	Contacts bomb plot and relays bomb run information. Cross checks bomb run review information as called by RN. Sets both radios to bomb plot frequency. Advises EW of any ECM restrictions	RN-Calls bomb run review - time to TIP, times and heading between targets, altitudes, tactics, etc. N-Directs pilot to accelerate to bomb run airspeed.
Turns aircraft to bomb run heading as called by N. Controls heading and altitude	Starts stop watch. Controls airspeed. Sets heading for second target into HSI.	RN-Calls TIP N-Calls bomb run heading and time to first target.
Centers FCI and adds it to instrument crosscheck.		RN-Directs pilot to center FCI and keep it centered.
Continues to fly low-level Monitors radar altimeter, TA display. Anticipate altitude charges and executes them smoothly while maintaining clearance plane.	Monitors aircraft position and informs pilot of deviations from centerline. Handles communications Manages fuel system and monitor electrical system.	N-Calls release configuration checklist. RN-Responds to release configuration checklist.
Keeps FCI centered	Monitors & controls airspeed, monitor	EW-Calls defensive maneuvers to pilot.
Receives & simulates defensive maneuvers as called by EW.	Monitors & controls airspeed, monitor engine instruments	RN-Requests TG calls from pilot
Checks to see that Bomb Release light is off. Hits press-to-test bulb.		

TASK NARRATIVES

Mission Segment: Low-Level Bomb Run

Page: 7

Time Frame:

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Begins TG calls at 150 TG (Calls made at 25 sec intervals until 60 TG). Keeps FCI centered.	Compares TG timing with TIP timing, announces large errors to crew.	
Calls 60 TG. Confirms clear terrain. Keep FCI centered.	Cross checks timing	N-Requests minor course corrections.
Calls 20 TG. Confirms tone is on. Makes minor heading changes as requested by N. Rolls wings level. Checks bomb doors open. Monitors bomb release at TG 0. Calls bombs away.	Cross checks timing.	RN-Calls bombs away.
Confirms tone break. Turns aircraft to heading for second target. Makes changes as called by N.	Makes bombs away call to bomb plot radio. Restarts stop watch.	N-Calls turn & heading to pilot for second target. Call updated timing.
Calls 20 TG. Confirms tone is on and bomb doors open. Makes minor heading changes. Rolls aircraft wings level.		N-Request minor course corrections

TASK NARRATIVES

Mission Segment: Low-Level Bomb Run

Page: 8

Time Frame:

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Confirms tone break. Calls bombs away. Turns aircraft to withdrawal heading, makes changes as called by N. Begins climb out.	Makes bombs away call to bomb plot radio. Starts stop watch for withdrawal timing. Reduces aircraft speed.	N-Calls bomb release. Calls turn & heading to pilot for withdrawal. Calls altitudes during climbabout. RN-Makes post release report to bomb plot.
Responds to checklist	Reads & responds to climb after low-level checklist.	
	1. Sets throttle	
2. Set autopilot low-level switch off.		
3. Set anti-icing & airbrakes to climatic.		
	4. Set TA mode switch off.	
	5. Set airconditioning to 7.45 psi.	
	7. Complete 12,000 ft oxygen check	G,RN-7 Complete 12,000 ft oxygen check.
8. Set altimeter to 29.92	8. Set altimeter to 29.92	N-8 Set altimeter to 29.92
9. Complete level-off checks.	9. Complete level-off checks	

Mission Segment: Low-Level Bomb Run

Time Frame:

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Perform station checks.	a. Turn taxi lights off b. Perform oxygen and station checks c. Set starter switches to climatic Call climb after low level checklist complete. Call Oakland center for clearance to FL 300.	

MISSION SEGMENT

RECOVERY

TASK NARRATIVES

TASK NARRATIVES

Mission Segment: Recovery Page: 1

Time Frame: 1105 Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Controls aircraft.	Calls command post to advise landing ETA, maintenance codes and fuel remaining.	
Monitors flight instruments as aircraft reaches SHADD, the initial approach fix. Begins decent from 16,000 to 10,000 feet, course 322° (R142), 240 KIAS.	Copies ATC handoff from Oakland to Castle approach. Change UHF 2 frequency. Request terminal weather, penetration type and establish time of penetration.	
Calls for completing the Decent and Landing checklist. Responds to checklist.	Reads and responds to the Decent and Landing checklist.	
12. Set altimeter.	12. Set altimeter.	N-12. Set altimeter.
Calls for landing gear down and verifies gear down.	12. Set landing gear down and verify.	
14. Set throttles.		
15. Set airbrakes at Position 4.		
16. Hook zero delay lanyard.	16. Hook zero delay lanyard.	EW, G-16. Hook zero delay lanyard.
Calls Castle Approach, 10,000 feet, continuing descent to 4,000 feet, course 322°, slow to 220 KIAS.	Check engine instruments. Check master monitor and caution indicators.	N - Make altitude calls.

TASK NARRATIVES

Mission Segment: Recovery — **Page:** 2

Time Frame: 1105 — **Date:** 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
17. Verify landing gear down.	17. Verify landing gear down.	
18. Request copilot to extend flaps.	18. Extend flaps, calls "50%" and "full down."	
	Copies Castle Approach handoff to Castle Tower for low approach and landing. Clears route onto the 13 DME arc.	
Turns on to the 13 DME arc.		
	19. Check center of gravity.	
20. Check fuel panel switches.	20. Set fuel panel switches.	
	21. Reads best flare speed, cross checks pilot's and copilot's best flare speed indicator.	N-21. Cross checks best flare speed.
22. Check crosswind crab.	22. Set crosswind crab.	
	Copies tower who gives distance to final approach fix, gives course and clears aircraft ILS final approach course.	N - Makes altitude calls.
Intercept the ILS glide slope. Follow glideslope down to decision height of 296 feet.	Informs tower on final approach fix.	
	23. Note target trim.	

TASK NARRATIVES

Mission Segment: Recovery — **Page:** 3

Time Frame: 1105 — **Date:** 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
	Copies tower clear to land.	
	24. Complete landing check. a. gears b. flaps c. airbrakes 4 d. lights	
	Monitors airspeed and altitude.	
Visually pickup runway.	Visually pickup runway.	N - Calls decision height.
Check trim indicators. Disengage autopilot. Rotate aircraft for landing. Retard throttles to cross end of runway at best flare speed.		

TASK NARRATIVES

Mission Segment: Recovery **Page:** 4

Time Frame: 1120 **Date:** 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Fully extend air brakes - order copilot to deploy drag chute.	Deploy drag chute.	N - Calls down at 1120.
Check and apply wheel brakes.		
Check all hydraulic pump lights off.		
Check crosswind crab control knob is centered.		
Slows aircraft to taxi speed.	Copies tower handoff to Castle ground control when off runway.	
Center rudder pedals and set steering ratio selector lever to taxi.		
	Copy ground parking instructions.	
	Calls command post to advise of final landing terminating mission.	
	Gives total flight time and fuel remaining.	
Taxi aircraft off main runway.		
Calls for After Landing checklist.	Reads After Landing checklist.	
Responds to checklist.		

TASK NARRATIVES

Mission Segment: Recovery | Page: 5

Time Frame: 1120 | Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
	1. Turn off landing light and cross-wind landing light switches.	
	2. Jettison drag chute.	
Pulls aircraft up to its parking spot.		
3. Sets parking brakes.		
4. Disengages yaw and pitch SAS switches.		
5. Turn off rudder/elevator hydraulic switches.		
6. Zeroize mode 4 and turn off the IFF.		
7. Turn off pilots flare set power switch.		
8. Set airbrakes lever off.		
9. Reset to zero and cutout stabilizer trim.		
10. Install arming lever safety pins (No. 1).	10. Install arming lever safety pins (No. 1).	
11. Stow armrests.	11. Stow armrests.	

TASK NARRATIVES

Mission Segment: Recovery | Page: 6

Time Frame: 1120 | Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
	12. Set starter switches off and pneumatic.	
13. Turn off TACAN and omni power.	13. Verify unnecessary electrical equipment turned off.	
Turn off Mach indicator switch.		
Turn off pitot heat switches.		
Turn off windshield and engine anti-icing switches.		
Turn off radar altimeters.		
Turn off autopilot master switch.		
Turn off liaison radio.		
14. Close and latch readiness switch cover.		
	15. Turn off generators 1 and 7	
16. Close throttles 1, 2, 7, and 8.	16. Close throttles 1, 2, 7, and 8.	
	17. Check fuel panel.	
	18. Open sliding window.	
19. Open bomb door switch.		
	Calls After Landing checklist complete.	

Mission Segment: Recovery

Page: 7

Time Frame: 1120

Date: 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
Calls for *Before Leaving Aircraft* checklist. Responds to checklist.	*Reads and responds to Before Leaving* Aircraft checklist.	
1. Check parking brakes set.		
	2. [illegible] anticollision and navigation [illegible]s to off and flash.	
3. Turn off EVS power switches.	3. Turn off EVS power.	
		RN-4. Turn off BNS and EVS.
	5. Turn off air conditioning master switch.	
6. Turn off gyro power switch.	6. Turn off gyro power switch.	
7. Open bomb door.		
	8. Turn generators 3 and 5 off.	
	9. Turn external power on.	
10. Close throttles.		
	11. Turn UHF radios off.	
	12. Turn off fuel panel switches.	
13. Set oxygen system to off and 100% oxygen.	13. Set oxygen system to off and 100% oxygen.	

TASK NARRATIVES

Mission Segment: Recovery | **Page:** 8

Time Frame: 1120 | **Date:** 20 January 1981

PILOT TASKS	CO-PILOT TASKS	ADDITIONAL AIRCREW TASKS
		GC-14. Wheel chocks in place.
15. Parking brakes off.		
16. Turn light switches off.	16. Turn light switches off.	
	17. Turn battery switch off.	
18. Stow control columns.	18. Stow control columns.	
19. Set seat positioning switch down and tilt forward.	19. Set seat positioning switch down and tilt forward.	
20. Turn off interphone power switch.		
	21. Pull generator drive decoupler circuit breaker.	
	Informs pilot Before Leaving Aircraft checklist complete.	
Leaves seat.	Leaves seat.	

APPENDIX B - ACTIVITY LOGS

TAKEOFF (PILOT)

Time	Input	Output	Verification	Anthropometry	Inf. Retrieval	Task Brief
000	A	V	N	Ø	N	COPIES CALL FROM GROUND CONTROL
002	A	V	N	Ø	N	COPY GROUND FOR FINAL WEATHER CHECK
002	A	V	N	Ø	N	COPIES TAKEOFF BRIEFING
005	V	N	N	Ø	Y	REVIEWS TAKEOFF PROCEDURE AND THE SID
006	N	V	N	Ø	Y	REVIEWS TAKEOFF CHECKLIST
015	N	N	N	1	N	RELEASES BRAKES
016	A	N	V	2	N	SET ENGINE STALL PREVENTION SWITCH TO CLIMATIC
016	N	V	N	0	N	CALLS "70 KNOTS,,NOW"
016	N	V	N	Ø	N	CALLS "COMMITTED"
016	N	N	V	1	N	APPLIES WHEEL BRAKES
016	N	V	N	Ø	N	"FLAPS UP"
017	N	N	V	3	N	SELECTS FLIGHT DIRECTOR FOR HEADING
018	N	V	N	Ø	N	"WATER-OUT EPR"
021	N	V	A	Ø	Y	CALLS AFTER TAKEOFF-CLIMB CHECKLIST
023	N	N	V	3	N	SELECTS FLIGHT DIRECTOR FOR NAV GUIDANCE
024	N	V	N	3	N	ENGAGES AUTOPILOT TO CAPTURE DESIRED HEADING
025	N	N	V	1	N	RESETS ALTIMETERS
035	N	N	V	2	N	SET THRUST GATE
035	N	N	V	2	N	SET STARTER SWITCHES TO CLIMATIC

TAKEOFF (COPILOT)

Time	Input	Output	Verification	Anthropometry	Inf. Retrieval	Task Brief
000	A	V	N	Ø	N	COPIES CALL FROM GROUND CONTROL
002	A	V	N	Ø	N	COPIES WEATHER
002	A	V	N	Ø	N	COPIES BRIEFING
004	A	V	N	0	N	"READY FOR TAKEOFF"
005	N	M	V	3	N	SWITCHES TO TOWER FREQUENCY
006	N	M	N	1	Y	REVIEWS TAKEOFF CHECKLIST
007	N	V	A	1	N	REQUEST PERMISSION TO TAKEOFF FROM TOWER
009	A	V	N	Ø	N	RECEIVES CLEARANCE FROM TOWER FOR TAKEOFF
009	N	M	V	3	N	SWITCHES TO DEPARTURE CONTROL FREQUENCY
015	N	M	V	3	N	CROSSWIND CRAB
016	N	M	V	2	N	AIR CONDITIONER TO RAM
016	N	V	N	Ø	N	SET BRAKES
016	N	M	V	1	N	FLAPS
018	A	M	N	Ø	N	"ROGER" TO DEPARTURE CONTROL
018	A	M	V	3	N	CHANGE COMM FREQUENCY
018	N	M	V	2	N	F/DIR SET
020	A	V	N	Ø	N	DEPARTURE CONTROL
021	N	M	V	2	N	AC TO 7.45 PSI
022	A	M	V	2	N	SQUAWK
022	A	M	V	Ø	N	CLEARANCE REC
022	N	M	T	2	N	A/P WARMUP
022	N	V	A	Ø	N	AUTOPILOT ON
023	A	V	A	Ø	N	DEPARTURE CONTROL "ROGER"
024	N	M	V	2	N	SET UP FUEL PANEL
024	N	M	V	3	N	CHANGE VHF FREQUENCY
025	N	M	V	1	N	ALTIMETER RESET
025	N	V	A	Ø	N	ACKNOWLEDGE ALTITUDE REQUEST
026	N	V	A	3	N	"ROGER" OAKLAND CENTER
026	N	M	V	3	N	CHANGE VHF FREQUENCY
033	N	V	A	1	N	"LEVEL AT FL 280"
033	N	M	V	3	N	COMM SWITCHED FROM CONTROL TOWER TO COMMAND POST
034	N	M	V	3	N	TURN LIGHTS OFF
035	N	M	V	2	N	SET THRUST GATE
035	N	M	V	2	N	SET STARTER SWITCHES TO CLIMATIC

ACTIVITY LOG - LOW LEVEL

Time	Input	Output	Verification	Anthropometry	Inf. Retrieval	Task Brief
000	N	Y	N	Ø	Y	"GET LL DESC CL"
002	Y	N	Y	1	N	TURN ON EVS TA VID
003	Y	N	Y	2	N	ANTI-ICING PANEL
003	Y	N	Y	2	N	CLEAR PLANE
003	Y	N	Y	1	N	RAD ALT TO 800 FT
004	Y	N	Y	1	N	SET ALTS
004	N	N	T	1	N	DUMP AP
010	Y	N	Y	3	N	AP TO LL
012	N	N	Y	1	N	CHK ALTS
012	N	N	Y	1	N	SET ALTS
020	Y	N	Y	1	N	CHECK GEAR, FLAPS UP
022	N	Y	N	Ø	N	"GET TA CHCKLST UP"
023	Y	N	Y	3	N	SET ALT HOLD AP
024	N	Y	N	1	N	CHK ALTS
025	N	Y	A	Ø	N	"YOUR AIRPLANE"
026	Y	N	Y	1	N	COMPARE STAB MODES
027	N	N	T	3	N	SET STAB REF SEL.
	N	N	Y	1	Y	FILL IN WORKSHEET
030	N	N	Y	3	N	PROFILE SET
031	Y	N	Y	1	N	READ RAD ALT.
032	N	N	Y	1	N	SET CL PLANE CAL VAL
033	N	N	Y	1	N	SET ALTS
033	N	N	Y	2	N	SET STAB REF SEL
034	Y	N	Y	3	Y	SET CL PLANE TO ALT
034	Y	N	Y	1	Y	SET RADALT CURSOR
036	N	Y	N	Ø	N	"I HAVE THE AC"
037	N	Y	N	Ø	N	RCVS BRUN HDG FM RN
042	Y	N	N	Ø	N	RCVS DEF MAN CMDS EW
044	N	N	Y	2	N	TURNS BOMB REL LITES

AIR REFUEL (PILOT)

Time	Input	Output	Verification	Anthropometry	Inf. Retrieval	Task Brief
000	A	N	N	Ø	N	HEAR RNAV CALL RANGE
003	V	A	A	Ø	N	"LEVEL AT FL290"
004	A	N	N	Ø	N	RNAV CALL
004	N	V	N	Ø	N	"BEGIN YOUR TURN"
004	V	V	A	Ø	N	"VISUAL CONTACT"
006	N	V	N	Ø	Y	"GET PREP CNTCT CL"
006	N	V	A	Ø	N	"LOUD AND CLEAR"
007	N	M	V	3	N	DISENGAGE AP
007	N	M	T	1	N	AIR BK SET
007	N	M	V	1	N	SET EVS FLIR VIDEO
008	V	V	A	Ø	N	"SPEED 270, CLIMBING"
008	N	M	T	3	N	AP TO AR MODE
010	A	V	N	Ø	N	BOOM OPS RADIO CK
011	A	V	A	Ø	N	"CLEAR TO CONT"
011	V	N	N	2	N	WATCH AR LITES
012	A	V	A	Ø	N	"CONTACT VERIFIED"
017	A	V	A	Ø	N	"PROBLEMS IN FUEL"
027	A	V	A	Ø	N	"ROGER, FUEL RCVD"
027	A	V	A	Ø	N	"DISCONNECTED"
050	N	V	N	Ø	N	"FINAL CONNECT"
052	N	V	N	Ø	N	"BRKAWAY PRAC"
062	N	V	N	Ø	N	"BREAKAWAYS"
063	N	M	T	1	N	DUMP AP AR MODE
064	V	V	N	0	N	"CLEAR TANKER"
065	N	V	A	Ø	N	"GET POST REF CL"

AIR REFUEL (COPILOT)

Time	Input	Output	Verification	Anthropometry	Inf. Retrieval	Task Brief
000	A	V	V	Ø	N	FUEL LOAD TANKER
003	V	V	N	Ø	N	"LEVEL OFF AT 290"
005	A	N	N	Ø	N	"RANGE IS 30 NM"
004	V	V	N	1	N	"TANKER SIGHTED"
006	N	V	A	1	Y	CHECKLIST
007	N	V	A	1	Y	CHECKLIST
007	N	N	V	2	N	TURN ANTICOLLISION LIGHTS OFF
007	N	N	V	Z	N	TURN NAVIGATION LIGHTS TO FLASH
008	N	N	V	2	N	SET SLIPWAY AND AIRPLANE LIGHT SWITCHES
008	N	N	V	2	N	OPEN SLIPWAY DOORS
009	N	N	V	1	N	DETERMINE TANKER POSITION ON FLIR
010	N	N	V	3	N	SET AIR REFUELING SWITCH TO AIR
011	N	N	V	2	N	RESET SIGNAL AMP
011	N	N	V	3	N	SET TACAN
012	N	V	A	Ø	N	INFORMS CREW CHECKLIST COMPLETE
010	A	N	N	Ø	N	COPIES BOOM OPERATOR'S RADIO CHECK
012	V	N	V	3	N	LIGHTING CONTROLS
012	A	N	V	Ø	N	"CONTACT"
013	V	N	N	2	N	VERIFY LIGHTS
013	N	V	N	Ø	N	"TANKS FILLING"
017	V	V	N	Ø	N	"CG MOVING FUEL"
018	V	N	N	1	N	FIND TANK THAT IS NOT FILLING
019	N	N	V	1	N	CLOSE 25-26 VALVES
019	N	N	N	Ø	Y	FUEL LOAD DETERMINATION
019	N	N	V	1	N	MANAGE FUEL PANEL
020	N	N	V	1	N	MANAGE FUEL PANEL
028	Y	V	N	Ø	N	"REFUEL COMPLETE"
029	N	N	T	2	N	SIG AMP
050	A	N	N	Ø	N	"CONTACT"
050	V	N	N	2	N	VERIFIES CONTACT ON REFUELING LIGHTS
051	V	N	V	1	N	FUEL MANAGEMENT
062	N	N	T	1	N	AP DUMP
062	N	N	T	1	N	BOOM RELEASE

ACTIVITY LOG - LOW LEVEL (PILOT)

Time	Input	Output	Verification	Anthropometry	Inf. Retrieval	Task Brief
000	N	V	N	Ø	Y	"GET LL DESC CL"
002	V	M	V	1	N	TURN ON EVS TA VID
003	V	M	V	2	N	ANTI-ICING PANEL
003	V	M	V	2	N	CLEAR PLANE
003	V	M	V	1	N	RAD ALT TO 800 FT
004	V	M	V	1	N	SET ALTS
004	N	M	T	1	N	DUMP AP
010	V	M	V	3	N	AP TO LL
012	N	M	V	1	N	CHK ALTS
012	N	M	V	1	N	SET ALTS
020	V	N	V	1	N	CHECK GEAR, FLAPS UP
022	N	V	N	Ø	N	"GET TA CHCKLST UP"
023	V	M	V	3	N	SET ALT HOLD AP
024	N	V	N	1	N	CHK ALTS
025	N	V	A	Ø	N	"YOUR AIRPLANE"
026	V	N	V	1	N	COMPARE STAB MODES
027	N	M	T	3	N	SET STAB REF SEL.
028	N	M	V	1	Y	FILL IN WORKSHEET
030	N	M	V	3	N	PROFILE SET
031	V	N	V	1	N	READ RAD ALT.
032	N	M	V	1	N	SET CL PLANE CAL VAL
033	N	M	V	1	N	SET ALTS
033	N	M	V	2	N	SET STAB REF SEL
034	V	M	V	3	Y	SET CL PLANE TO ALT
034	V	M	V	1	Y	SET RADALT CURSOR
036	N	V	N	Ø	N	"I HAVE THE AC"
037	N	V	N	Ø	N	RCVS BRUN HDG FM RN
042	V	N	N	Ø	N	RCVS DEF MAN CMDS EW
044	N	M	V	2	N	TURNS BOMB REL LITES

ACTIVITY LOG - LOW LEVEL (COPILOT)

Time	Input	Output	Verification	Anthropometry	Inf. Retrieval	Task Brief
000	A	V	N	Ø	Y	READ CL
001	A	N	V	2	N	CHECK BLEED SELECTOR SWITCH
001	A	M	V	1	N	TURN ON EVS AND SELECT TA VID
001	A	M	V	3	N	CHECK STARTER SWITCHES
001	A	M	V	2	N	SET STAB REF SEL SWITCH TO FVR
002	A	M	V	1	N	SET RADAR ALT CURSOR TO 800 FT
003	A	M	V	2	N	TURN TAXI LIGHTS ON
003	A	M	V	1	N	SET ALTS
004	N	V	A	1	N	CALLS OAKLAND "CANCEL IFR"
005	N	M	V	2	N	SET TERRAIN DISPLAY PROFILE 10
008	A	M	V	1	N	SET ALTIMETERS
025	A	V	N	1	Y	CHECKLIST RETRIEVAL
025	N	M	V	3	N	LOW-LEVEL AUTOPILOT SET
026	N	V	A	Ø	N	"CURRENT ALT"
026	A	M	V	1	N	SET ALT
032	N	M	V	1	N	SET RADAR ALT CURSOR TO TA ALT
041	N	V	A	Ø	N	RELAY BOMB RUN INFO
042	N	M	V	2	N	RADIOS
047	A	M	T	1	N	START WATCH
047	A	M	V	3	N	HSI SET
048	A	V	A	Ø	N	"COMM"
049	V	V	N	Ø	N	"ERROR IS 3 SEC"
050	V	V	Y	Ø	N	"BOMBS AWAY"
051	N	M	T	1	N	START WATCH
054	A	V	N	1	N	CHECKLIST
054	A	M	V	2	N	TA OFF
054	A	M	V	2	N	AC
055	A	M	V	1	N	SET ALT TO 29.92
055	N	M	V	2	N	TURN TAXI LIGHTS OFF
056	N	M	V	2	N	SET STARTER SWITCHES
057	N	V	A	Ø	N	"OAKLAND CENTER. . . "

ACTIVITY LOG - RECOVERY (PILOT)

Time	Input	Output	Verification	Anthropometry	Inf. Retrieval	Task Brief
002	N	V	N	Ø	Y	CALL DESCENT CLIST
002	A	M	V	1	N	SET ALT
003	A	M	V	1	N	SET AIRBRAKES
003	A	V	A	Ø	N	CALLS CASTLE APPROACH
004	A	N	V	1	N	VERIFY LANDING GEAR DOWN
004	N	V	N	Ø	N	REQ COPILOT TO EXTEND FLAPS
018	N	M	T	1	N	DUMP AP
019	N	M	T	1	N	AIR BRAKES
019	N	V	N	Ø	N	DRAG CHUTE
019	N	M	T	1	N	CHECK AND APPLY WHEEL BRAKES
020	N	V	N	1	N	CHECK ALL HYDRAULIC
020	N	V	N	1	N	CHECK CROSSWIND CRAB
020	N	M	V	2	N	CENTER RUDDER PEDALS
020	N	V	N	Ø	1	CALL CHECKLIST
021	V	M	V	2	N	DISENGAGES YAW AND PITCH SAS SW
021	V	M	V	2	N	ZEROIZE MODE 4 AND TURN OFF IFF

ACTIVITY LOG - RECOVERY (COPILOT)

Time	Input	Output	Verification	Anthropometry	Inf. Retrieval	Task Brief
001	N	V	A	Ø	N	CALLS COMMAND POST
001	A	N	N	Ø	N	COPIES ATC HANDOFF
001	A	M	V	1	Y	LOOK UP CASTLE APPROACH
002	N	M	V	3	N	CHARGE FREQ UHF
002	N	V	A	Ø	N	GET WX
002	A	M	V	1	Y	GETS DLC
002	A	M	V	1	N	SET ALT
003	A	M	V	1	N	L GEAR
004	A	N	V	1	N	VERIFY LANDING GEAR DOWN
004	A	M	V	1	N	FLAPS
005	A	V	A	Ø	N	COPIES CASTLE APPROACH
005	A	V	N	Ø	N	CHECK CENTER OF GRAVITY
006	A	M	V	1	N	SET FUEL PANEL SWITCHES
006	A	M	V	3	N	READS BEST FLARE SPEED
007	A	V	A	Ø	N	SET CROSSWIND CRAB
009	A	V	A	Ø	N	INFORMS TOWER ON FINAL APP FIX
017	A	N	N	Ø	N	"CLEAR TO LAND"
019	A	M	V	2	N	DRAG CHUTE
020	A	N	N	Ø	N	COPIES TOWER HANDOFF
020	A	N	N	Ø	N	COPY GROUND PARKING INSTRUCTION
020	N	V	A	Ø	N	CALLS COMMAND POST
020	A	M	N	1	Y	READS AFTER LANDING CHECKLIST
021	N	M	V	2	N	JETTISON DRAG CHUTE

APPENDIX C - QUESTIONNAIRES

TAKEOFF/RECOVERY

1. During Takeoff or Recovery, if you could call up a checklist (and display it on the EVS) by voice command

   Example: "Descent Checklist"

   Always very Useful ______ | ______ | ______ + ______ | ______ | ______ Never Useful

   Sometimes Useful

2. During landing, if altitude calls could be automatically read by voice generation.

   Example: "Two hundred ... "

   Always very Useful ______ | ______ | ______ + ______ | ______ | ______ Never Useful

   Sometimes Useful

3. During TO or Recovery, if P or CP could change radio freqs by short verbal request.

   Examples: "UHF, three-two-seven."
   "TACAN, Panoche."
   "VHF, Castle Approach"

   Always very Useful ______ | ______ | ______ + ______ | ______ | ______ Never Useful

   Sometimes Useful

4. During any mission segment, if the MCP warnings or messages could also be voice generated.

   Example: "Fuel Flow"

   Always very Useful ______ | ______ | ______ + ______ | ______ | ______ Never Useful

   Sometimes Useful

5. In Recovery, if CP or P could set altimeter by voice command.

Example: "Altimeter, niner-three zero"

Always very Useful — Sometimes Useful — Never Useful

6. In TO or Recovery, if P or CP could set Radio Nav Instruments by voice.

Examples: "Heading, NOR"
"Mode, TACAN"

Always very Useful — Sometimes Useful — Never Useful

7. During TO or landing, if P or CP could call up data (e.g., SID map, performance data).

Example: "Show SID, Edwards"

Always very Useful — Sometimes Useful — Never Useful

8. If IFF mode and code could be selected by voice.

Example: "IFF code, one-niner-three."

Always very Useful — Sometimes Useful — Never Useful

9. If air conditioning master select switch could be controlled by voice.

Example: "Air off"

Always very Useful ______ | ______ | ______ ______ | ______ | ______ Never Useful

Sometimes Useful

10. If Airspeed calls could be done by voice generation instead of P or CP calls during TO.

Example: "One-eight-zero knots"

Always very Useful ______ | ______ | ______ ______ | ______ | ______ Never Useful

Sometimes Useful

11. If Flight Director could be manipulated by voice command during TO or Recovery.

Example: "TACAN, Merced"

"TACAN-Mode"

Always very Useful ______ | ______ | ______ ______ | ______ | ______ Never Useful

Sometimes Useful

12. If the fuel panel (CP) could be set up and controlled by voice commands.

Always very Useful ______ | ______ | ______ ______ | ______ | ______ Never Useful

Sometimes Useful

13. If the autopilot controls could be changed by voice command.

Example: "AP, low level"

"AP, Altitude"

"Disengage"

Always very Useful ——— | ——— | ———+——— | ——— | ——— Never Useful

Sometimes Useful

14. The steering ratio selector changing from taxi to takeoff-land by voice.

Always very Useful ——— | ——— | ———+——— | ——— | ——— Never Useful

Sometimes Useful

15. The CP currently calls the position of the flaps (e.g., 50%, full down). This could be voice generated leaving CP eyes free.

Always very Useful ——— | ——— | ———+——— | ——— | ——— Never Useful

Sometimes Useful

AIR REFUELING

16. Voice command could be used to control all the CP functions of the Refueling panel (e.g., auxiliary tank switches, main manifold interconnect).

Always very Useful ——— | ——— | ———+——— | ——— | ——— Never Useful

Sometimes Useful

17. Voice command could set anticollision lights to OFF/ON or navigation lights to FLASH/STEADY.

Always very Useful			Sometimes Useful			Never Useful

18. Reset of sig. amp button could be accomplished by voice command.

Always very Useful			Sometimes Useful			Never Useful

19. The slant range calls could be made by speech generation, in 10 NM increments.

Always very Useful			Sometimes Useful			Never Useful

20. The EVS mode selection could be done by voice control.

Example: "EVS-FLIR"
"EVS-LTV"

Always very Useful			Sometimes Useful			Never Useful

21. The information on the eybrow panel, (e.g., ready-for-contact, contact made, and disconnect light) could be reinforced through voice generation.

Always very Useful ______ | ______ | ______+______ | ______ | ______ Never Useful

Sometimes Useful

LOW LEVELS

22. If the TF calls could be given by voice in addition to the EVS readings in 10 second increments . . .

Always very Useful ______ | ______ | ______+______ | ______ | ______ Never Usefui

Sometimes Useful

23. Bleed selector switch could be checked by voice command, and status given back by voice generation.

Example: P - "Bleed selector status"

SG - " LH-INBD"

Always very Useful ______ | ______ | ______+______ | ______ | ______ Never Useful

Sometimes Useful

24. Clearance planes could be changed/set by voice.

Example: "Clearance 8 hundred"

Always very Useful ______ | ______ | ______+______ | ______ | ______ Never Useful

Sometimes Useful

25. Stabilization Reference Selector could be changed by voice.

Example: "SRS - FVR"

Always very Useful ______ | ______ | ______ + ______ | ______ | ______ Never Useful

Sometimes Useful

26. Radar altimeter cursor could be set by voice command.

Example: "Radar altimeter 8 hundred"

Always very Useful ______ | ______ | ______ + ______ | ______ | ______ Never Useful

Sometimes Useful

27. Taxi lights could be turned off-on by voice command and verified by voice generation.

Always very Useful ______ | ______ | ______ + ______ | ______ | ______ Never Useful

Sometimes Useful

28. Terrain display mode selector switch profiles could be changed by voice command.

Example: "Profile Ten"

Always very Useful ______ | ______ | ______ + ______ | ______ | ______ Never Useful

Sometimes Useful

29. Record keeping on TA performance during calibration (e.g., working with calibration worksheet) could be voice controlled.

Example: "Clearance plane setting___ ___ ___ ___."

"Bias compensation ___ ___ ___ ___ ."

Always very Useful ______ | ______ | ______|______ | ______ | ______ Never Useful

Sometimes Useful

30. Heading set into HSI by voice.

Example: "Heading, three-one-zero"

Always very Useful ______ | ______ | ______|______ | ______ | ______ Never Useful

Sometimes Useful

31. The Start/Stop watch sequence could be controlled by voice and verified by voice response.

Always very Useful ______ | ______ | ______|______ | ______ | ______ Never Useful

Sometimes Useful

APPENDIX D - RECOGNITION TASKS

AIR CONDITIONING CONTROL

This is a low priority task from the crew member's viewpoint. Frequency of occurrance is intermittant and fluctuates with climate changes.

VOCABULARY CONTENT:

First Node: RAM, OFF, 745-PSI, 450-PSI, Temperature

Second Node: (For temperature only) warmer, cooler, off

Implementation:

IWR: "Air conditioning, temperature, cooler"

CWR: "Cool cabin"

IWR: "Air conditioning-745PSI-"

CWR: "Set air conditioning to 745PSI"

AIR REFUELING PANEL CONTROL

Control of the air refueling panel is the duty of the copilot during the AR mission segment. Interactions are periodic throughout this segment. This task was judged only moderately useful for AST because of the lack of time-sharing and anthropometric demands. One task within this set, reset of signal amp, was judged to be highly useful for AST, however.

VOCABULARY CONTENT

<u>First Node</u>: Power on, signal amp, slipway lights, airplane lights, slipway doors, toggle latch.

<u>Second Node</u>: (Signal amp) reset, manual, normal; (slipway lights) brighter, darker, off; (airplane lights) brighter, darker, off; (slipway doors) normal, alternate, toggle/latch release, hold.

<u>Implementation</u>:

IWR: "Refuel--airplane lights--brighter" "Refuel--sig amp--reset"

CWR: "Increase brightness of airplane lights" "Reset sig-amp"

ALTIMETER SETTINGS

Altimeters are set repeatedly during a mission, especially during the recovery phase and low levels. This example refers to the pressure altimeter. Task can be done by both crew members.

VOCABULARY CONTENT:

Single Node - Digits 0-9, point

Implementation:

IWR: "Altimeter-two-niner-point-seven-two-go"

CWR: "Altimeter-twenty-nine-seventy-two"

AUTOPILOT CONTROL

The control of autopilot modes is done frequently in several segments. A fairly simple vocabulary could be used to change the state of this system.

VOCABULARY CONTENT:

Single Node: Release, Low-Level, Air-Refuel, Approach, Altitude Control

Implementation:

IWR: "Autopilot-Air Refuel"

CWR: "Change Autopilot to Air Refuel Mode"

CHART RETRIEVAL

This task was chosen in part because of several pilot interviews. It was learned through these briefings with crews that it is often necessary to refer to the "dash-ones" to retrieve SID and aircraft performance data during a mission. Assuming a large scale data base storage system, this retrieval process could be implemented using the EVS as the main display vehicle. The main savings here is time due to manual search.

VOCABULARY CONTENT:

Single Node: Angle-of-attack, Brake Limits, Buffet Boundary, CG Limits, Crosswind, Engine Limits, Flap Performance, Flare Speeds, FRL Settings, Glide Slopes, Hydroplane Speeds, Lateral Control, Load Factors, Maneuver Limits, Roll Rates, Sink-Speed, Speed Envelopes, Takeoft Factors, Takeoff Flight Paths, Thrust Gate

Implementation:

IWR: "Charts-CG Limits"

CWR: "Display CG Limits Chart"

CHECKLIST RECALL

Checklists are the main operating procedure of the aircraft. The recall of lists is continuous throughout the mission. Recall by speech was judged highly useful by pilots. The vocabulary problem is not as severe as the emergency procedures, but still may present problems.

VOCABULARY CONTENT:

Single Node: Taxi, Pre-takeoff, Takeoff, Landing, After-takeoff, Rendezvous, Prep-for-contact, Low-level descent, Climb after low-level, Descent-and-Landing, TA System Cal, TA Function Check.

Implementation:

IWR: "Checklist-Taxi." "Checklist, Pre-Takeoff"

CWR: "Display taxi checklist" "Display pretakeoff checklist"

CIRCUIT BREAKER STATUS

Many of the circuit breakers are located in a remote position from the forward stations. The incidental pop of a circuit breaker can go undetected, and the pilot or copilot must request thegunner to check for certain breaker status.

VOCABULARY CONTENT: Digits, Breaker, Out

Implementation:

CWR: P-"What is status of breaker twenty-four?"

SG-"Twenty-four breaker out."

IWR: P-"Breaker Status--two--four."

EMERGENCY PROCEDURES RECALL

The ability to retrieve any emergency procedure from the "dash-ones" was judged to be very useful by the pilots. Since the task would be of a verbal nature, it is a natural for AST. The vocabulary content would be large, however, and could present some implementation problems for speaker dependent systems. It is assumed that the EVS would be used to display retrieved information.

VOCABULARY CONTENT:

First Node: Inflight, Landing, Systems

Second Nodes: (inflight) shutdown, air starting, smoke fumes, fire, autopilot, ejection steps, descent, ALE; (landing) gear tail, partial gear, wing flaps up, ditch-crash; (systems) hydraulic fail, generator trip, generator overheat, shutdown, amp flux, electrical system, power conserve, AGM-69.

Implementation:

IWR: "Emergency-Inflight-Shutdown" "Emergency-Landing-Partial Gear"
CWR: "Display Inflight Emergency Shutdown Procedure"

EVS MODE CONTROL

This task is performed by either crew member periodically during air refueling and low level.

VOCABULARY CONTENT:

First Node: FLIR, STV, TA, LOS Command

Second Node: (LOS command) vector, fixed, crab

Implementation:

IWR: "EVS--TA" "EVS--LOS command--crab"

CWR: "Change EVS to TA mode" "Change EVS LOS command to crab"

FLIGHT DIRECTOR CONTROLS

Interactions with the flight director are few in cruise segments, but frequent in takeoff and landing. This task was judged useful for speech recognition. The vocabulary list and implementation procedure would be the same as that listed for navigation system control.

FUEL MANAGEMENT

The copilot's fuel management responsibilities are not limited to switch opening/closure between tanks. The monitoring of quantities in each tank is a critical part of the total task. Pilots suggested the interaction with the fuel quantity sensors to provide certain programmed warnings to occur when fuel drops below specified levels.

VOCABULARY CONTENT:

<u>First Node</u>: One, Two, Three, Four, mid body, forward body, aft body, left/right outboard, center wing, left/right external

<u>Second Node</u>: Digits, thousand, hundred

Implementation:

IWR: "Fuel Management--Left Outboard--six-thousand--over."
CWR: "Warn when left outboard less than six thousand pounds."

FUEL PANEL CONTROLS

This task, usually performed by the copilot, consists of manipulating a series of two-position switches on the right side of the main cockpit panel. All switches are labeled with a numbering scheme. Suggested implementation would assume a toggling system whereby the voice command would change the state of the knob upon recognition of that switch number (i.e., from OPEN to CLOSED).

VOCABULARY CONTENT:

Single Node: Main-One, Main-Two, Main-Three, Main-Four, digits (0-9)

Implementation:

IWR: "Fuel Control-three-go"

CWR: "Change fuel valve three to OPEN (CLOSED)"

HEADING SELECTION FOR HSI

HSI interactions occur several times during the mission, and are performed by either crew member. This task was judged useful for AST application.

VOCABULARY CONTENT:

First Node: Heading, Course, Mode

Second Node: (Heading) digits, (Course) digits, (Mode) grid, magnetic

Implementation:

IWR: "HSI--Heading--One--Three--Five" "HSI--Mode--Magnetic"

CWR: "Change HSI heading to one-three-five." "Change HSI mode to magnetic."

IFF MODE SELECTION

This task is accomplished in takeoff.

VOCABULARY CONTENT:

First Node: Mode-One, Mode 3 A, Code A, Code B, Hold

Second Node: Digits

Implementation:

IWR: "IFF-Mode One-zero-seven"

CWR: "Change IFF Mode to zero seven"

LIGHT CONTROLS

The interior and exterior lights are periodically controlled by the copilot according to ambient conditions.

VOCABULARY CONTENT:

First Node: Navigation, anti-collision, thunderstorm, dome, crosswind, terrain clearance, air refueling

Second Nodes: (Nav) flash, off, steady, bright, dim; (anti-collision) off, on; (thunderstorm) off, on; (dome) red, white; (crosswind) off, on; (terrain clearance) off, on; (air reference) off, on.

Implementation:

IWR: "Lights--navigation--steady" "Lights--dome--red"

CWR: "Change navigation lights to steady" "Change dome light to red"

MASTER MODE SELECTION

This task represents the initiation point for all IWR task transactions. It is not a necessary task assuming CWR. It is assumed that prompting upon recognition of one of the vocabulary items would appear either on the EVS or through voice generation. Subsequent syntax node prompts would also appear on EVS or be speech generated.

VOCABULARY CONTENT:

Air Conditioning	Emergency	I-F-F	Refuel Panel
Altimeter	EVS Mode	Lights	Steering Ratio
Autopilot	Fuel Control	Nav System	TA-CAL
Charts	Fuel Management	Radar Altimeter	Terrain Display
Checklists	H-S-I	Radios	
Circuit Systems			

NAVIGATION SYSTEM CONTROL

The radio nav system is reset periodically during takeoff and recovery, and occasionally during cruise and other segments in conjunction with flight direction controls. Note the great simplification of this task through the use of facility names instead of numeric inputs. This obviates the need for time-costly look-ups of unfamiliar facilities or navigation aids.

VOCABULARY CONTENT:

First Node: TACAN, VOR, ILS, ILS-Approach, Heading Set, Heading Mode

Second Node: Digits, point; NOR, Manual

Implementation:

IWR: "Nav System-VOR-one-one-zero-point-three-go" ("Nav System-VOR-Castle")

CWR: "Change Nav VOR to VOR one one zero point three" ("Change Nav System VOR to CASTLE")

IWR: "Nav System-Heading set-zero-niner-two-go"

CWR: "Change Nav System Heading to zero nine two"

IWR: "Nav System Heading Mode-Manual"

CWR: "Change Nav System to Heading Mode to Manual"

RADAR ALTIMETER CURSOR SETTING

This task is frequently done by crew in low level bombing. Often occurs during high visual time sharing. Could be especially useful when TA equipment is down.

VOCABULARY CONTENT:

Single Node: Digits, Hundred

Implementation:

IWR: "Radar Altimeter--eight hundred"

CWR: "Radar altimeter to eight hundred"

RADIO FREQUENCY CHANGES

This task occurs frequently during takeoff and recovery segments, often without warning. The copilot usually handles this task. CWR becomes advantageous in the input of the channel or frequency because of the sequential digit entry.

VOCABULARY CONTENT:

First Node - HF, UHF, TACAN, VHF

Second Node - 0-9, point

Implementation:

IWR: "Radio-HF-one-four-point-three-five-go"

CWR: "HF-fourteen-point-three-five"

RECORD KEEPING IN TA CALIBRATION

Performed by pilot during entry into low levels. Requires pilot to switch between worksheet, visual displays, and outside world. AST was judged useful for application in this task by pilots. Could be especially useful for "on-line" computational work.

VOCABULARY CONTENT:

First Node: Error Type, Compensation, Compute

Second Node: (Error) Complete dropout, partial dropout, side dropout, weather effects, bias errors, tilt errors, tile and bias; (Compensation) Peak tilt, peak bias, flat roll bias, flat roll tile; (Compute) digits

Implementation:

IWR: "TA CAL--Error Type--Partial drop out"

CWR: "TA Partial drop out error"

START TIMER IN BOMB RUN

A simple task now done with manual stopwatch by copilot. Would allow attention to outside world if controlled by voice.

VOCABULARY CONTENT:

<u>Single Node</u>: "Start timer/Stop timer"

STEERING RATIO SELECTION

This task was not judged as "useful" by the pilots. It consists of a two-state switch control which is usually toggled by either crew member. It does not require visual contact with the switch.

VOCABULARY CONTENT:

Single Node: Taxi, Takeoff, Landing.

Implementation:

IWR: "Steering ratio-takeoff."

CWR: "Change steering ratio to takeoff."

TERRAIN DISPLAY CONTROL

Frequently adjusted in low-levels, this task scored well on utility for AST. Most helpful in profile switching operations.

VOCABULARY CONTENT:

First Node: Profile Three, Profile Six, Profile Ten, SRS, Clearance Plane

Second Node: (SRS) fuselage, vector, horizontal; (Clearance Plane) digits, hundred

Implementation:

IWF: "TA--Profile Three" "TA-SRS--Vector" "TA--Clearance Plane--Eight Hundred"
CWR: "TA mode to Profile three." "SRS to vector reference." "Clearance Plane 800."

APPENDIX E - GENERATION TASKS

ALTITUDE/AIRSPEED CALLS

This task was recommended for AST due to high time sharing component during takeoff and recovery. The critical points only would be enunciated (e.g., S_1 and S_2 speeds, altitude in specified intervals.) Vocabulary is numerics.

VOCABULARY CONTENT: Digits, Hundred, Thousand.

CONTACT-DISCONNECT CALLS DURING AIR REFUELING

Air refueling conditions could be enunciated via voice generation. These conditions are indicated presently by a lighting system on the eyebrow panel.

VOCABULARY CONTENT: Ready for Contact, Contact Made, Disconnect

FLAPS POSITION VERIGICATION

This task would be used to enunciate the position of flaps during takeoff, low levels, and recovery, or whenever a change in position has occurred. It was judged very useful by pilots because of the high probability of occurrence during time-sharing segments. Malfunction indication was recommended by pilots.

VOCABULARY CONTENT:

Flaps Half, Flaps Full, Flaps Up, Flap Manfunction

MASTER CAUTION PANEL ENUNCIATION

The Master Caution Panel (MCP) is the main method of warning crewmembers of impending or present emergencies or deterioriation in certain systems. The "H" model contains an MCP, however, the "G" model does not. Therefore, the addition of speech to enunciate these 21 warnings/messages was judged very useful for the "G" model.

VOCABULARY CONTENT: N=50 words, all fixed phrases

AC Breaker Open	Engine Oil Overheat	IFF Mode 4
Aft Battery Out	Forward Battery Out	Main Tank Low
Autopilot Off	Fuel in Cabin Manifold	Pitch SAS Off
Battery Reset	Fuel in Main Manifold	Starter not Off
Bomb Doors Open	Generator Overheat Reset	TPG Not in Trail
Bomb Doors Unlatched	Hatches Unlocked	Wing Tanks Reset
Bomb Released	Hydraulics Reset	Yaw SAS Off

SLANT RANGE CALLS

The distance from the tanker is given by the navigator during the approach to the air refueling point. If this could be automatically given by speech generation, this would free navigator of one visual task.

VOCABULARY CONTENT: Digits, Miles, Range.

TO-GO CALLS DURING LOW LEVEL

For each bomb target, the navigator makes a series of "to-go" calls prior to reaching the target coordinates. These calls are in seconds and direct the release of the ordnance. The time is also projected on the EVS display. Speech generation would eliminate having to look at the EVS during these intervals.

VOCABULARY CONTENT: Digits, Ten, Twenty, Thirty, Forty, Fifty